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A SYMPOSIUM ON MINING AND METALLURGICAL EDUCATION

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SCHOOL *of* MINES *and* METALLURGY

UNIVERSITY *of* MISSOURI

MINING AND METALLURGICAL EDUCATION

A Collection of Papers on the Subject, including the Discussion Presented at the Meeting of the Committee on Education and Public Service of the American Mining Congress, Chicago, October, 1921.

Edited by
CHARLES H. FULTON

A LIST OF ARTICLES ON ENGINEERING EDUCATION

By
MRS. H. O. NORVILLE, Librarian

ROLLA, MISSOURI

1922

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BULLETIN

OF THE

School of Mines and Metallurgy

UNIVERSITY OF MISSOURI

GENERAL SERIES

VOL. 14 JANUARY, 1922. NO. 1

SYMPOSIUM ON ENGINEERING EDUCATION.

The Education of a Mining Engineer.*

By T. A. Rickard.

When starting a discussion it is well to begin by defining the terms to be used. What is a mining engineer? The word 'mine' comes from the Latin *mina*, an excavation underground for destroying a fortification; later it meant a hole in which an explosive was placed for a belligerent purpose. Thus we have the word 'undermine.' Hamlet says:

> "But I will delve one yard below their mines,
> And blow them at the moon."

The original meaning of the word 'mine' survives in 'menace,' a threat, and in 'minatory,' a synonym for 'threatening.' The word 'engineer' likewise comes to us from the technology of the Roman soldier, for it is derived from *ingenium*, a military device, a war-engine, a battering ram. The derivation is more evident in the French spelling, *ingenieur*. The idea of inventiveness survives in the word 'ingenious,' and it fits the engineer, who is skillful in originating. The military connotation of the two words 'mining' and 'engineer' was revived during the recent war, when our professional friends and kinsmen came from the Yukon and California, from New Zealand and Missouri, from the remotest corners of the earth, to join in fighting in behalf of the great cause. One member of our profession, Ralph S. G. Stokes, who in the first week of the war, went from New York to London to enlist as a private in the British regiment of Royal Engineers and rose by force of merit to the rank of Lieutenant-Colonel, served as 'Controller of Mines'

*Address delivered on the occasion of the Semi-Centenary of the School of Mines, November 5, 1921.

in Flanders; he supervised the preparations for the tremendous 'blow,' or explosion, at Messines on June 6, 1916. That was a truly great 'mine' in the original sense of the word.

You will recall Mark Twain's definition of a mine as "a hole in the ground owned by a liar." The definition is amusing; but many an untrue word is said in jest; the liar is not the honest prospector of whom we think as the owner of a young mine, but a much less responsible person, the promoter, whose regard for truth is so great that he rarely uses it, the so-called fiscal agent who converts an honest excavation into a purring 'wild-cat,' with claws—and whiskers! I insist that the mining engineer is connected with a legitimate form of industry, the main purpose of which is to make money by winning the valuable metals and minerals from their rocky matrix within the crust of the earth. The object of mining is not—as is supposed by some—to spoil the scenery of the beautiful parts of the earth or to afford employment to the sons and nephews of the favored few. Nor is it the primary purpose of mining to obtain cross-sections for the elucidation of geologic problems or to gather data concerning the increment of temperature in depth. No; the motive of mining is neither academic nor altruistic; it is, in plain English, to make money, honestly, by producing the metals and minerals essential to the very existence of our material civilization. Engineering has been defined as "the art of directing the great forces of Nature for the use and convenience of man." That is the motto of the Institution of Civil Engineers in England. On the United Engineering Societies building in New York it is written: "Engineering, the art of organizing and directing men, and controlling the forces and materials of nature for the benefit of the human race." This is idealistic, and not wholly true, for the art of engineering is applied usually not with benevolent purpose but for honorable gain—to the engineer himself, to his employer, to the community. but rarely for the express benefit of the human race. That is too large an order. Again, it does not seem to me correct to define engineering as "the art of organizing and directing men." That is preeminently the art of the politician! A man can be a great engineer without ever taking charge of the men that do the work of construction. He is better for the experience, but it is not essential to his art. However, when we do think of mining engineering as used for the benefit of mankind, we think of Herbert C. Hoover, who applied his experience as a manager of mines to a great humanitarian task. He fed ten millions of Belgians and French at a total administrative expenditure of less than half of 1%—to be exact, 0.42%—of the cost of the entire operation. That reminds me of a story.

Several years ago Mr. Hoover was crossing the Atlantic and happened to sit at table next to a British gentlewoman of the

early Victorian type. After passing the salt and offering the Worcester sauce once or twice, he became acquainted with her as one does aboard ship. He told her of his travels in China and Mexico, in Australia and Burma, and she found the young man both agreeable and interesting. Near the end of the voyage, by which time they had become pleasantly acquainted, she asked him, "What are you, Mr. Hoover?" He answered, "An engineer." "Oh!" she exclaimed, "I thought you were a gentleman!" She thought an engineer was an engine-driver; and probably to her a gentleman meant a person without visible means of support. If she lived to the time of the Great War and read of Mr. Hoover's achievements as dispenser of nutrition in Europe and as Food Administrator in the United States, she may, in her quiet home in rural England, have awakened to the fact that an 'engineer' may be several kinds of a man, and sometimes, as Shakespeare says, "he is a proper man's picture."

Well, what is a mining engineer? I know of only one definition that is sufficiently comprehensive: he is a man that does the work of a mining engineer, namely, the management of mines, the examination and appraisal of them, the work of surveying underground, the planning and devising of ways and means for winning ore. A degree from a University or a School of Mines does not make a mining engineer; the degree merely certifies to an adequate scholastic preparation for the work. Many graduates from mining schools have never practiced the profession for which they were prepared; they have become brokers or druggists, for example. On the other hand, sundry brokers and druggists have dropped their original vocations and learned enough of the art of mining to examine mines, to appraise them, and even to manage them. When they did that they were mining engineers—some of them may not have been the best of their kind, but they earned the designation by doing the work. I am reminded of the New York City boy who was on a summer excursion in the country and asked the teacher, "What kind of a 'boid' is that?" You know that the boys from the East Side say 'thoity-thoid' for 33rd, 'foist' for first, and 'boid' for bird. So this boy asked, "What kind of a 'boid' is that?" The teacher said, "That is not a 'boid', it is a bird." "But," replied the boy, "it makes a noise like a 'boid.' " It did. So a man that makes a noise like a mining engineer—talks like one, does his work like one—is a mining engineer, whether he be duly certified or not. In some States he must be licensed, and if he can show a diploma it is easier for him to obtain a license—for example, a shorter period of apprenticeship is required—but otherwise he has the same chance as his friends—for they are friends—whom we may term 'diplomatic' because they have diplomas. It is well that this should be so, for our American ideal is the equality of opportunity; we recognize no privileged class, even of scholars;

it would be unfair to debar any young man from reaping the reward of the training that is acquired in irregular ways, by night study, by association with helpful seniors, by reading, observing, and experiencing the things requisite to the development of capacity as a professional man. Several honored members of our profession entered it by the side-door—not the back. One distinguished veteran was a carpenter and the son of a carpenter, with none of the advantages typified by such an institution as the Missouri School of Mines. Another began life as a sailor; a third, as an accountant; a fourth, as a botanist. I am speaking of men now acknowledged to be in the first rank. Many, of course, began life as laborers in mines and mills; starting to do manual work when their more fortunate comrades of the future were still at school. The chief difference between them and the 'regulars'—those who underwent the conventional training—is that they acquired their knowledge more slowly, more laboriously, and they reached positions of emolument comparatively late in life. The chief purpose of school or college is to learn how to learn. The preparatory school to which I went has for its motto: "*Non scholae sed vitae discimus.*" "We learn not for school but for life." It is perfectly logical, for example, when licensing a man as an engineer or admitting him to membership in a professional society, to require, as a qualification, more years of responsible service from a non-graduate than from a graduate, because an unschooled mind is slower to apprehend than one that has been trained.

Here we come to the definition of education. Education is the process of educating; the word is derived from the Latin *e*, out, and *ducere*, to lead; it means the leading out or bringing forth of the innate powers of an individual; it means the bringing up or rearing of a child; and it applies to the children of a larger growth, to us all, whose education continues throughout life, until our mental faculties become atrophied. 'Live' and 'learn' are conjoined advisedly, for when we cease to learn we may as well die. It is said that John Richard Green, the historian, asked that his epitaph might be, "He died learning."

So we have considered the meaning of the terms used in our subject, the education of a mining engineer. It means the proper training of the young man who intends to do the special work that is required in connection with mining. Mining is an art, or a skillful method of doing things; to it the various sciences are applied with a view to improving the method. So we learn mathematics, mechanics, physics, mineralogy, and geology; the knowledge obtained is less important to us than the manner in which it is obtained, for what we learn in a school or a college is of small consequence, and soon forgotten, as compared with the training of our mental faculties so that we may be able to think clearly, observe accurately, and state truthfully. This we cannot do unless

we use our language properly, for truthfulness of statement depends upon the proper use of the words that are the symbols of thought. Therefore we engineers should learn how to speak and write—particularly to write—intelligently and intelligibly. Of all the instruments of precision used by a mining engineer the one that he uses most is his own language—the language that came from the old country, from Chaucer and Spenser, from Steele and Addison, from Shakespeare and Milton. It is a beautiful language and a flexible instrument of expression. Our mining engineers are well grounded in the various 'ologies;' they have been well drilled in the requisite number of sciences; but they do not appear to see the prime necessity of acquiring the one accomplishment without which the others may prove ineffectual. I shall speak plainly.

During recent years public attention has been drawn to the need of teaching English, more particularly to those who are undergoing training for an engineering career, because it has become recognized that our profession is sadly lacking in the ability to speak and write effectively. We—you and I—may be especially critical of this defect because we know that is necessary to use the language correctly in describing or discussing technical operations and ideas; but defective English is common to our American youth generally—boys and girls alike. Much has been said on the subject and many are the causes to which these shortcomings are ascribed. I venture to be frank with you in stating that one cause is our democratic way of living. Do not mistake me; I am keenly in sympathy with the democratic idea; I believe it to be the best stimulus for the further progress of our civilization, and I believe that the destiny of our country is to develop the idea of democracy for the benefit not only of ourselves but of the world at large. If we are intellectually honest, however, we must recognize the fact that democracy levels down as well as up. For example, you and I, the audience and the speaker, belong to the professional class, a class that is differentiated not by wealth but by education, by the possession and use of brains that have been trained for our several vocations. Our children go to the public schools, which follow the democratic custom of allowing all children, of whatever class, to share the same instruction. I use the word 'class' as the equivalent of 'type,' not to signify any recognized social stratification as in Europe. Our children at school sit side by side with others that come from homes where defective English is spoken, from the homes of aliens who have not learned to speak our language properly, from the homes of those of our own native stock who did not go to school in their youth or who for other reasons are illiterate. The children sit together and they play together, in good democratic fashion; they acquire the same habits of speech; the young negro, the young Japanese, the young Italian, the grocer's boy, the hod-carrier's son, the laborer's girl, the par-

son's son, the professor's daughter, all sympathetically and naturally acquire the same kind of language. The result is that those who speak it badly learn to speak it less badly, whereas those who speak it well, learn to speak it less well. That is why the children of our professional men do not speak as well as their similars in England, whereas the children of the laborer, the hod-carrier, the plumber, and the grocer speak and write much better than their similars in the old country. There the sons of professional men go to school with the sons of other professional men—to schools that resemble our private schools—where they do not associate with those reared in illiteracy. The effect is to perpetuate a social distinction; to make good speech a mark of class. We obliterate the class distinction, we sacrifice the facility for acquiring correct speech to the supreme ideal of our democracy, namely, an equality of opportunity. I do not cavil at it; it is worth while, but we must recognize the penalty—a small one relatively—that we pay for the sake of our ideal.

Next comes the question, should we continue this system of education in common although it have a result prejudicial to a part of the community? Speaking broadly it seems to me that we should continue to sacrifice the literacy of a few for the sake of educating the many, and that a division of our children according to class or vocation would be a step backward; but we can remedy the obvious consequence by insisting upon more and better teaching of English in our schools and universities. For example, our mining schools should make it a part of their duty to improve the speech and writing of their students by maintaining a class in English at least for the freshmen, as most of them do already, and by requiring a good standard of writing throughout the successive years spent in technical education. An examination paper in mechanics or mineralogy, in physics or geology, should be required to reach a standard not only in the knowledge of the science but also in the art of expression. It may be said that it is no part of the duty of a School of Mines to teach English, which should have been taught to the student in the high-school. The answer is that we face a condition, not a theory; and if the students come insufficiently trained in a matter so important as the use of their language, it is only fair and wise to give them the necessary training before it may be too late. I note that in this School of Mines three hours per week during the first and second years are allotted to English; in this respect you set a good example.

Next I shall refer to another cause of poor speech and bad writing. Many of our young men seem to think it democratic and American to talk in a slovenly way; and the habit, I think, affects their writing. When college graduates start to work at the mines they desire to seem "practical" as soon as possible, and in order to be friendly with the workmen they are deliberately careless in their

speech, avoiding nicety of expression as if it were effeminate. Some, I am sorry to say, appear to think it necessary to imitate the "mucker" and acquire methods of speech common to illiterate workmen, as if it were manly, as if in protest against the highbrow or academic cult. In consequence, many young fellows from homes of refinement, the sons of well educated parents, the graduates of great colleges, the pupils of distinguished scholars, talk and write deplorably. It is a huge blunder to suppose that such a failing is either democratic or American. To be either one or the other it is not necessary to be unseemly in manner or uncouth in speech; on the contrary, I say with confidence that a young American democrat should aim to be as courteous in manner, as decent in bearing, and as correct in speech as any aristocrat of the old world, but he should be just 15% more intelligent. It is intelligence that classifies men in a democracy. The greatest democrat of all, Abraham Lincoln, did not think it improper to speak and write carefully. In his public utterances, spoken or written, he endeavored to use good English; indeed, he developed a skill that made his speeches and writings models of classic excellence. It remains a perpetual miracle that a man with so few educational advantages should have acquired such a mastery of the language that the best of his utterances are unexcelled in the literature of our race. The Gettysburg speech and the Second Inaugural address are, and will remain forever, models of exquisite diction and consummate oratory. How did Lincoln acquire this remarkable skill? First, he had few books to read, but they were of the best: the Bible, "Pilgrim's Progress," Shakespeare, Aesop's "Fables," and Blackstone. His mind sought good company. He walked miles to borrow a book on grammar and he gave his spare time to it while tending the village store. I like to think of young Lincoln lying at full length on the counter of Greene's store at New Salem, his head propped on a pile of calico prints, while he read "Kirkham's Grammar," or sitting in the shade of a tree while he studied Blackstone's "Commentaries," which he found among some discarded papers at the bottom of a barrel. He did not have to read the yellow press of today or even the dialect stories in our current magazines; so he escaped the contagion of jargon. His Gettysburg speech contains only three words not in the Bible; they are "continent," "proposition," and "civil," but all three are to be found in Shakespeare. He drank freely at that well of English undefiled, the King James version of the Bible. The language of the Bible and of Shakespeare is the best part of our familiar speech. Here I may mention that now no student at Harvard can receive his degree without passing an examination in the Bible; indeed, the authorities at Cambridge rank the Bible and Shakespeare as "two works of literature without which an adequate appreciation of English letters is impossible." This rule is not prompted by

devotional or religious motives, but by the same cultural considerations as caused Huxley to advocate the reading of the Bible in the public schools of London. To good books Lincoln owed much; but in part his astonishing skill was due to another cause, only recently made known. He lived in an illiterate community and among people who spoke badly; when listening to his associates and hearing their yarns in the local store he noted their inability to express themselves successfully; he thought about it, and made the experiment of putting their sayings into more careful language; he would go home and write down the story that had been told clumsily and then proceed to put it into better words; that is, he edited what his friends had said. Thus he gained skill in the use of speech; he realized that there was a technique of language and he set himself to acquire it; and he did acquire the technique so thoroughly that his words, warmed by his genius and glorified by his spirit, will echo forever down the corridors of time.

So, gentlemen, no American can say that it is undemocratic to speak like a gentleman or to write like a scholar. On the contrary, we technical men, who have to deal with subjects requiring precise presentation, should be particularly desirous of using the instrument of expression with care. The difference between good and bad writing is chiefly the difference between being careful and being careless. It is not difficult if one desires to do so, to learn to write respectably. To acquire the art of Lincoln, of Ruskin, or of Stevenson there is needed more than care, more than conscious effort; but ordinary skill, sufficient for most of us, can be acquired by anyone willing to take pains. Genius has been described as one part inspiration and nine parts perspiration; we can be nine-tenths of a genius if we have the capacity for working with sincerity of purpose. Only recently I overheard a woman say to her companion in a suburban train: "I'd like to be able to write clearly without stopping to think about it." She was one of many, of those who would like to do a thing well without the trouble of thinking; but it cannot be done in respect of anything to which thought is essential. However, she was not unlike some of my young friends in the mining engineering profession who use the chisel of language as if it were a screw-driver. It is astonishing how many graduates from universities will write: "The data *is* sufficient," "the propaganda *are* objectionable," "the agenda *was* printed." An Assistant Principal in a School of Metallurgy wrote to me that he observed "*this* same phenomena in other kinds of glass;" and, as if to show that the error was not inadvertent, he repeated it twice. When I wrote in a kindly way to warn him, he apologized, but intimated that he was rather pleased with his skill in writing. How often we read of proposals to tax "the necessities of life," as if being subject to necessities were not sufficient cause for unhappiness

without our being taxed on account of them. The tax is levied on the "necessaries," the staple articles, not the necessities that they satisfy. This use of the abstract instead of the concrete is characteristic of the windy utterances of politicians. It reminds me of the Babu—a half-educated Hindoo—who, when declining an invitation on account of the death of his mother, wrote: "Regret I cannot come, the hand that rocked the cradle has kicked the bucket."

Well, I have said enough concerning one phase of the education of mining engineers; if I say more you will charge me with attempting to make journalists of them. After all, before one writes one must have something to say. As to that, I doubt if any men have more opportunities to gain information and to see the world at large than the members of our profession. American engineers have gone to the remotest corners of the globe, following the lead of their British comrades. In South Africa and Western Australia they have made their mark; in Canada and South America they fill today many of the chief positions in the management of famous mining enterprises. They have participated in the development of the principal mines of Siberia. Just now the shrinkage of capital and the temporary abatement of the spirit of mining adventure have restricted their activities abroad, but the time is coming when they will be called again in large numbers to foreign fields of activity. The reason they are wanted is because they are efficient, particularly in their clear-headed appreciation of the business side of mining, plus an intimate acquaintance with the latest technology. The United States can boast many excellent mining schools—that of Missouri is one—but the reason why our men are effective is due to the larger fact that the United States is a great mining country; indeed, it is a continental area in which are found many mining regions of diversified character, yielding nearly every one of the metals and minerals required by our material civilization. We may be short of tin and antimony; we may not possess deposits of chrome and manganese so generous as those to be found elsewhere; but in a broad way our country is exceptionally endowed with mineral resources. Therefore it offers a post-graduate school of mining unsurpassed in the world at any period of human history.

Another condition favorable to the development of competent mining engineers in the United States is the social status of our profession. If one of you were to take a young Englishwoman in to dinner and ask her what was her idea of a mining engineer, she would say, probably: "A somewhat nomadic person connected with queer doings on the Stock Exchange." An American girl would reply differently; she would, I believe, intimate that the mining engineer was a half-back with a scientific education, competent to dig gold out of the ground and to manage men at least

as well as the colonel of a regiment. In England the mining engineer ranks socially below the officers of the army and navy, below the barrister and physician, below the people who live on the rents from land and the coupons from bonds; indeed, the profession is so young compared with the survivals of an ancient system that it has not yet come into its own. In our country the mining engineer may call at the White House and shake hands with the President as a matter of course. When Cecil Rhodes established his scholarships at Oxford he aimed to promote international goodwill, but, although he had gained his wealth in mining, it did not occur to him to found a College of Mines at Oxford. If he had done that, he would have accomplished a great benefaction for the profession and for the mining industry of the British empire, but such an educational foundation would have been a complete departure from British tradition—especially at Oxford, "the home of lost causes and forsaken beliefs." In our own country the chief mining schools are attached to, or are integral parts of, our universities. That is as it should be. Most of our engineers have enjoyed some of the advantages of a university education along with their technical training. It is becoming recognized that the preparation for a bread-and-butter dependency, for a salaried "job," is not an education in its true sense, and that to make men of real worth, likely to be happy and useful, prepared to do the work of the world as effective citizens, there must be some culture, some bringing forth of the faculties that distinguish *homo sapiens* from the rest of the *genus homo.* "Man does not live by bread alone." If our great experiment in democracy is to succeed it will be by reason of "the moral worth and intellectual clearness of the individual citizen." The mob can not help, nor will the yellow press; education can do it by bringing the right men into leadership. The University of Missouri and its School of Mines can forward the consummation of a great ideal, and I feel confident that they will.

It has been my privilege to know most of the leading mining engineers of the world, in this and in other countries, during the last thirty years, and I am informed concerning the careers of many of them. In a broad way they are an exhibit for the educational methods of the last quarter of the nineteenth century. What can we learn from their biographies?

In the first place, the successful mining engineer—the man who has won the esteem of his fellows and established himself in an extensive and lucrative practice as a manager of mines or as a consulting engineer—is not always a college graduate nor even a man trained in a mining school. About one in seven has missed these advantages. I use the word "missed" advisedly, for if he had been better educated he would have been even more useful and efficient. The lack of educational advantages and the compara-

tive poverty of his parents to which this was due have had the effect, however, of compelling him to work harder and have tended more strongly to develop his character—to make him industrious and self-reliant. To be given a good education and to start life without the urgent need of earning a living is not always the best thing for a young man, especially if he lack initiative and ambition. In a democracy, as in other types of social organizations, it will be found that those who are born with a silver spoon in the mouth are likely to die with gold filling in the teeth, without having accomplished anything more decorative. It is proper that we should admire the man who makes his own way. For example, your own most distinguished alumnus started life as a poor orphan lad, reared on a small farm; he earned money for his schooling by hard work; by dint of personal effort he won his way to this School of Mines and here obtained the lever by which he opened the world oyster, in the shape of the greatest copper mine on this continent. To give an education to such men is the finest investment a nation can make.

When I review the life-histories of the men whom I admire and respect I realize how much their university education has expedited their mental development and hastened their arrival at positions of influence. Only men of extraordinary force of character have been able to achieve success without such help, and, it is sad to say, they represent the few survivors of hundreds who failed for the lack of such help. In the days to come the chances of the unprepared will be even less, for the demands made upon engineers in the way of scientific training, will become increasingly exacting.

Much of men's success seems to be due to accident. This one was lucky in making the acquaintance and arousing the personal interest of a leader; that one happened to be on hand when a particular post had to be filled in a hurry; another had the special experience required for a special piece of important work at a given time and place; a fourth had personal qualities that won the goodwill of the president of a company or the manager of a big mine—and, needless to say, gentlemen, I rate the manager of a mine above the president of a company. So it seems as if much of life were fortuitous; as if men became successful through accident. This is a superficial view; on the contrary, it will be found, on closer scrutiny, that the success is due to the man being ready for his chance; to his having prepared himself for many contingencies, so that when opportunity knocked at the door he was ready to rise and give instant welcome to the visitor. Our own deeds are our doomsmen.

"There is a tide in the affairs of men,
Which, taken at the flood" [to which Byron added]—"you know the rest,
And most of us have found it, now and then;
At least we think so, though but few have guessed
The moment, till too late to come again."

Some, like children, only wade in the shallows and so fail to feel the greater impulse out at sea; they fear to swim in deep water and are left behind, high and dry. Our life is as "the sands betwixt two tides."

The difference between men is chiefly the difference of character. Education develops character—that is the very essence of education. A man of character goes through the shoals of circumstance as a ship directed by a captain with a compass and a chart; a man lacking character is like a ship without control that drifts upon the reef and suffers shipwreck. Herbert Spencer said that "of all the ends to be kept in view , . . all are unimportant compared to the end of character-making. This alone is national education." In the last resort mere cleverness will not take a man far; there is needed something more dependable, and dependability is character. A man of character will act in the same way under the same conditions. Give a man of character a liberal education and he becomes the finest product of our civilization. It is the product that an educational institution such as yours aims to give to the United States—worth more than much fine gold or a million tons of copper. A liberal education is the aim of all true scholastic effort; but there is no complete agreement as to the necessary curriculum. After all, a liberal education is the product of an ideal that transcends the curricula of the schools. Permit me to quote from the greatest expositor of the nineteenth century, Thomas Henry Huxley:

"That man, I think, has had a liberal education who has been so trained in his youth that his body is the ready servant of his will, and does with ease and pleasure all the work that, as a mechanism, it is capable of; whose intellect is a cold-logic engine, with all its parts of equal strength and in smooth working order; ready, like a steam-engine, to be turned to any kind of work, and spin the gossamers as well as forge the anchors of the mind; whose mind is stored with a knowledge of the great and fundamental truths of Nature and of the laws of her operations; one who, no stunted ascetic, is full of life and fire, but whose passions are trained to come to heel by a vigorous will, the servant of a tender conscience; who has learned to love all beauty, whether of Nature or of art, to hate all vileness, and to respect others as himself."

Huxley was the Dean of the Faculty of the Royal School of Mines—my alma mater—a school that was royal not by reason of kingly patronage but because it had for teachers such men as Huxley, John Tyndall, Lyon Playfair, Edward Forbes, and John W. Judd. Gentlemen, permit me to transmit to you this description of a liberal education as the greeting of the Royal School of Mines of London to the School of Mines of Missouri on the occasion of its 50th anniversary.

SYMPOSIUM ON MINING EDUCATION.

The meeting of the Committee on Education and Public Service, American Mining Congress, October, 1921, was attended by the representatives of fifteen educational institutions that give courses in mining and metallurgical engineering. As a preliminary to the meeting a questionnaire was sent to educational institutions offering courses in mining and metallurgy. This questionnaire is as follows:

SYMPOSIUM ON MINING EDUCATION.

1. What should be the scope and content of a course in Mining or Metallurgy?
2. Can the co-operative system in Engineering as practiced by the University of Cincinnati be successfully applied in a mining and metallurgical education?
3. What is the best way to make room in a mining or metallurgical course for the constantly increasing number of technical subjects which apparently should be included?
4. What are the basic elements of a mining and metallurgical course?
5. Should the mining and metallurgical course as ordinarily given be recast and rebuilt and if so on what basis?
6. Are four years enough for a course in mining or metallurgy, taking into consideration all elements that enter into this problem?
7. How is the subject of mining best taught?
8. How is the subject of metallurgy best taught?
9. How much mathematics should there be in the mining course? In the metallurgy course?
10. What is the best way of teaching English to Engineering students?
11. Should the English for Engineering students be technical and limited in character or broad and include literature?

Written papers were submitted and the questions were also discussed informally at the meeting and practically all of the material is published in this bulletin.

ANSWERS TO QUESTIONS OF THE SYMPOSIUM ON MINING EDUCATION.

[D. C. Livingston, Oregon State Agricultural College.]

1. I think the scope and content is pretty well covered by most of the present mining school curricula, except for the fact that the general mining and metallurgical curriculum is often too narrow, and should be broadened to include more subjects of educational value which the student cannot get outside in after life, except by considerable effort.

2. Not in a position to answer this, but do not think it very practicable.

3. Leave them out of a four-year course.

4. Basic sciences such as Chemistry, Physics, Mathematics and Geology, with their application to the work of mining and metallurgy, and also the ability to write and speak corrrect English. Drafting and surveying should also be included.

5. Yes, I believe it should on the following basis: Have the basic sciences, such as Chemistry, Physics, etc., taught by mining engineers and metallurgists who would illustrate the fundamental principles by actual examples in metallurgical practice and mine plant design. This would be a great time saver and would eliminate a lot of lost motion which exists at the present time between the fundamental sciences and their application. It would enable such courses as Metallurgy and Mining Engineering to be much reduced, and more time would be available for the student to *get an education* as well as *technical training.* The latter is all he gets under the present system.

The principles of geology are always illustrated by actual natural examples, as well as by laboratory experiments. Why not do the same with Chemistry for instance, and in addition to the laboratory experiments, illustrate its application to metallurgy, and thus impress the student's mind with the principles and practice at the same time. This I believe would be preferable to the disconnected manner in which these subjects are now taught. In the same way, why not, in certain cases, have Descriptive Geometry taught to mining students by a geologist, as there is surely no other place where it is more useful to be able to visualize on two or more planes.

6. I think four years are long enough for an under graduate course in Mining or Metallurgy if it is sufficiently broad. If a student wishes to specialize in any particular subject, he should take that as post graduate work, possibly after a year or two of practical work.

7. and 8. Could be answered in so many different ways that I do not care to discuss it.

9. I do not think that Calculus is of inestimable value in either mining or metallurgy as it is now considered.

10. and 11. I believe that some guide along lines of literature should be given to students. Possibly certain novels or books assigned for summer reading, and an examination in the fall held with some discussion later, as well as the technical side of the English language.

12. If it is the consensus of opinion among the engineering profession and the public in general that a technically-trained man along one line is an educated man, then I think the mining and engineering schools are performing their duty well and efficiently on the whole. If on the other hand, an educated man is considered to be one who possesses a knowledge of the government of his country, a knowledge of humanity gained from the past history of mankind, a knowledge of more than one language than his own, a knowledge of business methods, and at least a speaking acquaintance with the literature of his language, in addition to a knowledge of the basic sciences necessary to his profession, then it is evident that the technical schools are not turning out educated men. The men that they are turning out are but a slight degree better educated than a highly skilled carpenter or mechanic. It is my belief that if an equal number of young men took a four years' course at college, one of which was along broad educational lines with surveying and assaying included and some lectures on the mining industry and its relation to the sciences, and the other group took the present narrow prescribed courses and both entered the mining profession, from ten to twenty years after graduation the first group would be more likely to contain the higher percentage of leaders or men well up in the profession.

ANSWERS TO QUESTIONS OF THE SYMPOSIUM ON MINING EDUCATION.

[Charles E. Newton. Oregon State Agricultural College.]

1. The scope of a modern course in Mining and Metallurgy should include basic courses necessary to the solution of the technical mining and metallurgical problems. A training in mathematics, physics, chemistry, and drawing, taught with the idea that they are not taught for the sake of themselves, but taught with the idea that they are tools to be used in the solution of problems that are to follow in the business. In conjunction with these subjects, a thorough grounding in the geologic sciences and in the arts of mining and metallurgy.

2. At the present time I am of the opinion that it is impractical to have a co-operative system in Mining and Metallurgy as is practiced in the University of Cincinnati. It might be possible that a co-operative system of this kind could be carried on in the ferrous mining and metallurgical line.

3. The best way to make room in a mining and metallurgical course for the increased number of technical subjects is to require all the students who enter mining courses to have had one or two years' training in a general science course of a university nature. The student will then be prepared to master more quickly and more thoroughly the basic sciences necessary in the mining and metallurgical curricula.

4. A thorough understanding of physics, chemistry, mathematics, and drawing,—drawing with the idea of expressing facts in a graphical way.

5. All engineering courses should be recast on the following line: The student should have a general college or university education before entering the school. If this arrangement could be complied with, technical graduates would be better educated and better trained, technically. As it is at the present time, most of them are poorly educated and not very well trained technically.

6. Four years are not time enough for a course in mining and metallurgy. How much time is required, I am not prepared to say. I do believe, however, that four years is more than time enough for the technical side if the student has a good general education before he attempts to receive his technical training.

7. The subject of mining is best taught by lectures, illustrated as well as descriptive, mining trips to actual mining operations, with complete notes, sketches and photographs of the operations visited and studied.

8. Same for metallurgy as for mining.

9. Enough mathematics to solve general mining and metallurgical problems. That would perhaps include a good under-

standing of algebra; good training in trigonometry; good training in descriptive geometry; elementary training in calculus. My idea along this line is that these subjects be not taught for mathematics sake, but be taught in the technical training courses, as a tool to be used in the solution of a problem—not purely for the solution of some mathematical dream.

10. The best way to teach English to engineering students is to teach them to write technically after they have been taught to read and appreciate our better authors of classical literature.

ANSWERS TO QUESTIONS OF THE SYMPOSIUM ON MINING EDUCATION.

[J. H. Batcheller, Oregon State Agricultural College.

1. In my opinion, the scope and content is very well covered by the required studies for a degree in Mining in the School of Mines here.

2. For those Schools of Mines which are conveniently located in the neighborhood of operating mines, I should think a co-operative system of engineering education could be applied successfully. For those institutions which are geographically remote from active mining operations, I should think it would be impracticable. The same answer applies to metallurgical operations, whether fire or hydrometallurgy.

3. In my opinion there is no way, good or otherwise, to constantly crowd the curriculum of the School of Mines with the new technical subjects, and continue granting degrees in a four-year period. The best solution in my mind is adhering faithfully to the old idea of thorough grounding in the basic elements of the mining and metallurgical work, and giving those other courses as options for those who have extra time, or as advanced standing subjects for those who can put in more than four years' school attendance.

4. The basic elements in my opinion are now as they have always been: Mathematics, Chemistry, Physics, Geology, Drawing, Applied Mechanics, Technical Electricity, Surveying, Hydraulics, and all the various subdivisions of the strictly mining, metallurgical and geological subjects.

5. I don't know but what it would be best to recast the mining and metallurgical courses with the idea of requiring all students to pass through a two-year course of semi-vocational nature, which would include practical work as indicated in answer to Question 2. For this they would get a certificate but not a degree. Only to those whose practical and academic standards showed they had genuine ability might be offered a four-year stiff course in the advanced theoretical work leading to a degree of Engineer of Mines. This would give time to include many of the desirable, but at present impossible extra technical subjects. The above proposed six-year course leading to the degree of E. M. is based on the supposition that the present method of teaching Mathematics, Chemistry, Physics, Descriptive Geometry, and Applied Mechanics be continued by instructional staff outside of that of the School of Mines.

If, however, it were possible to so provide that for all students of mining, the instructors in the above basic subjects just mentioned could be mining engineers and geologists of practical ex-

perience as well as high theoretical attainments, then the course of work in these basic subjects could be taught with just as much thoroughness with regard to the fundamental principles involved, and in addition the students would get a far greater grasp and understanding of the practical value of each of these items as applied to their mining work through the practical illustrations that these experienced instructors could use to illuminate their subjects. This would reduce the present lost motion, because it seems to be the invariable condition that the student in Descriptive Geometry has to practically review that subject when his time comes to study geologic faulting problems. The same condition seems to be a normal state of affairs with regard to many of the other practical applications of applied science. By the elimination of this lost motion, a saving of time would be accomplished. During the time thus saved, I would recommend that it be divided and a portion added to that already devoted to each of the following cultural subjects, namely, English Literature and Composition, History and Governments of the World, and Political Economy.

Of the two plans or outlines I have given above in answer to Question 5, I personally favor the latter, but presume that it would be too expensive in salaries. Surely the qualifications necessary to secure the type of instructional staff outlined as necessary for this scheme, would not be obtainable except at what would probably at this time be considered prohibitively high figures.

6. This is answered by my reply to No. 5.

7. Mining is best taught, in my opinion, by means of lectures and explanatory comments, referring to references assigned for reading, supplemented by visits some time before graduation to operating properties. This method would also include recitations and quizzes, to develop the understanding to which the students have been able to follow the lectures and reading assignments. While not now feasible on account of the expense, I believe it would be a vast improvement if some synthetically constructed moving pictures could be made to illustrate many of the complicated operations of the modern caving methods of mining, showing in fifteen minutes the successive steps of a cycle of operations which might in actual practice require two or three years for completion, and be so complicated that it would be impossible to express them satisfactorily by any few simple diagrammatic drawings.

8. I see no better way of teaching Metallurgy than seems to be universally employed, namely, lectures, recitations, laboratory work based on the above, supplemented by visits to operating plants.

9. With regard to Mathematics in either mining or metal lurgical courses, I am not at all satisfied that it is inevitable and necessary that the students must drag their weary way through all the calculus now required. I am not in a position to offer a substitute suggestion, but think that inside of another twenty years, there will be a change in attitude towards calculus, except for men of special calibre for highly technical design work. Calculus will then probably be looked upon very much as the present day public looks upon the necesity for Latin and Greek as a preparation for the modern boy's life work. For a long while it was thought that no other subject could be found equal to the Latin and Greek of old, but I think that idea has been proven to be a mistake.

10. and 11. Regarding these, I think one answer covers both. The present method of teaching English to engineering students by means of lectures and compositions seems to be all right, provided, however, that the students be allowed to write compositions on some subjects in which they have personal and genuine interest, presumably on some phase of mining, metallurgical, or geological work. By all means I consider the English training should require broad and comprehensive reading of the fine things in classics, supplemented by explanatory lectures to help them grasp the value and meaning of such.

MINUTES OF THE MEETINGS OF THE COMMITTEE ON EDUCATION AND PUBLIC SERVICE, AMERICAN MINING CONGRESS.

October 18, 19, 1921.

The meetings were held in the Congress Hotel, Chicago. An invitation to attend the meetings of the Committee had been sent to many schools and universities offering courses in mining and metallurgy.

A list of the institution represented and those in attendance follows below:

PROFESSOR J. R. NELSON, *University of Michigan.*
DEAN P. F. WALKER, *University of Kansas.*
PROFESSOR C. R. HAYWARD, *Massachusetts Institute of Technology.*
DR. DORSEY A. LYONS, *U. S. Bureau of Mines.*
MR. C. H. FULTON, *Missouri School of Mines and Metallurgy.*
PROFESSOR F. W. SPERR, *Michigan College of Mines.*
DEAN G. M. BUTLER, *University of Arizona.*
PROFESSOR A. L. WALKER, *Columbia University.*
MR. N. S. GREENSFELDER, *Hercules Powder Co.*
DEAN E. S. MOORE, *Pennsylvania State College.*
PROFESSOR H. H. STOEK, *University of Illinois.*
PRESIDENT C. C. O'HARRA, *South Dakota State School of Mines.*
PROFESSOR A. H. CARPENTER, *Armour Institute of Technology.*
DEAN F. A. THOMSON, *University of Idaho.*
PRESIDENT E. H. WELLS, *New Mexico School of Mines.*
PROFESSOR A. J. HOSKIN, *University of Illinois.*
PROFESSOR C. J. NORWOOD, *University of Kentucky.*

The Executive Committee for 1922 is as follows:

Mr. C. H Fulton, Chairman, Rolla, Mo.,
Director Missouri School of Mines and Metallurgy.
Dean F. A. Thomson, Moscow, Idaho.,
Dean School of Mines, University of Idaho.
Dean G. M. Butler, Tuscon, Ariz.,
Dean School of Mines, University of Arizona.
Dr. D. A. Lyon, Washington, D. C.,
Superintendent of Stations, Bureau of Mines.
Professor A. L. Walker, New York, N. Y.,
Professor of Metallurgy, Columbia University.
Dean E. S. Moore, State College, Pa.,
Dean School of Mines, The Pennsylvania State College.

CONFERENCE HELD TUESDAY, OCT. 18, 1921.

MR. FULTON:* I welcome you on behalf of the Committee on Education and Public Service of the American Mining Congress. The name is an inclusive one, as you will note, and just how it originated I cannot tell you, but the Committee was formed in St. Louis two years ago, and met again last year, in Denver, when an Executive Committee was appointed of which I was made the chairman. The Executive Committee outlined a proposed program, the main feature of which was to be a symposium on mining education. During the past year, the Committee was in correspondence with many of those interested in mining and metallurgical education requesting them to present papers and discuss pertinent subjects. We are here for that purpose today.

The program for today is to discuss some of the questions, an outline of which was sent to those expecting to take part in this conference. One of these questions is that of English in the mining and metallurgical course and the paper by Professor Nelson of the University of Michigan bears directly on this subject. Professor Nelson represents the Committee on English of the Society for the Promotion of Engineering Education.

PROFESSOR NELSON READS HIS PAPER: "The Development of a Special English Course for Engineering Students." (Published in Proc. Soc. Prom. Eng. Ed.)

MR. FULTON: Prof. Nelson's paper is on a vital subject. Those here who have had to do with engineering training will concede this. On the whole, students entering technical schools have poorer preparation in English than in former years. Why this is so I do not know, but I believe it can be traced in part to the less severe training the student gets in high school, because the high school course is so crowded with odds and ends as to curtail fundamental studies. If it is true that men entering the technical schools are less efficiently trained in English than formerly it is essential for the technical school to correct this deficiency. In what manner this is to be done I do not know, but Prof. Nelson has offered good suggestions. One of the subjects under discussion is "Should the English taught in technical schools be of a technical character or should it be general in character." I gather from Prof. Nelson's paper that his conception of the task of the English Department is to make the men acquainted with English from the standpoint of literature.

†DEAN WALKER: In Kansas we have a separate department of English for engineering students, doing in some lines at least so far as our organization permits, the same that Michigan

*School of Mines and Metallurgy, Univ. of Mo.
†University of Kansas.

does, and I wish to corroborate what Prof. Nelson has said as to the change in the attitude of these men. I recall 10, 12 or 15 years ago the student looked upon English work more or less as a bore, and I now hear the most enthusiastic comments from them with reference to the work they are doing in advanced composition. Only juniors and some seniors are admitted to that class. We never put a man in below the junior year. With reference to the report writing work, we have a Kansas custom of requiring 4 technical reports, prepared by students under the direction of the members of the technical department, and it interests me greatly to know that the English Department of Michigan is taking over that work. Is that required or elective?

PROF. NELSON: That is required and is a two-hour course. I lecture one hour a week and have a conference group of about 10 seniors for the other hour. I insist that all the work on the report be done under my direction, which shows how to go about the proposition of organizing technical material when you have that proposition before you and how to get the best result. They do all the work on that report under my direction and the report comes to me first. I cut it all to pieces and insist on rewriting it and putting it in the best form possible. Technical men claim there has been great improvement.

DEAN WALKER: I wish to mention one other thing that Prof. Nelson has spoken of and that is the necessity that the technical teaching staff back up the English Department in holding forth the importance of English training work. I never lose an opportunity of driving that in.

PROF. HAYWARD*: Our students are all studying engineering and since the founding of the school it has been a policy to require substantial courses in English. Unfortunately the study of English was not always popular and even such an eminent scholar and teacher as the late Prof. Arlo Bates was often annoyed by indifferent or even antagonistic students. I think that attitude has largely disappeard in recent years. Some of our English staff are among the most popular men on the faculty. They have tried to make English appreciated by the students and if they have not wholly succeeded they have at least made it less disliked. By means of evening readings and other voluntary services some of the instructors have made a secure place in the student life.

In addition to the required English courses of the first two years we require that a certain amount of time in the junior and senior years be given to what we term "general studies." These are selected by the students from a given list of non-technical or so-called "cultural" subjects. Most of these are given by the

*Mass. Inst. Tech., Boston.

English department. Among them is report-writing in which the student is allowed to select his own subject, often getting advice from a member of his professional department, studying it in the library and then submitting his report to the English department for correction. In this way two ends are served. The student gets technical information along a line in which he is interested and then learns how to express himself in correct English. In spite of continued pressure for more time in professional subjects the faculty has always rigidly stood against obtaining it at the expense of English, history, economics and similar general studies.

PROF. SPERR*: The assertion has been made that the high school graduates are not as well trained in English as they used to be. Is it not because we are impressed with their lack of training more than we used to be? I rather think it is that we are getting just as good training in high school graduates now as we ever did, but the trouble with the training in English in technical schools is eventually due to the same thing as it is in our high schools —the lack of teachers with the proper personnel and pep in them to get anything into a student at all. When high school students hate the study of English, I think it is largely because of the lack of proper personnel in the teacher. I think if we could in some way get at our normal schools for training the teacher and get at our high school organizations or the directors to impress upon them the necessity of better English teaching in their schools, we could accomplish something. English is made a sort of a by-play, a good thing to have, but not necessary. That is the attitude—anybody can teach English. I assume that the object of teaching English is to train the student to use good English in both speaking and writing. The necessity for the use of good English depends on either of these lines and you do not have to confine yourself to technical subjects or think you have to make it either technical or literary, or both. Successful teaching of English to engineering students depends largely on the instructor if he must interest the young men in the subject and make them realize that they need to use good English for their own personal efficiency and success.

MR. FULTON: I think that the high schools are in part responsible for the poor training in English, and still it is not fair to generalize, for we will find that in the large cities, high schools often give most excellent training in English; but when the country schools and the country high schools are considered we find that there has crept into the course of study of these schools the vocational training idea, and that this vocational training is largely of a so-called practical nature which takes up so much time, that the really fundamental studies—reading, writing, spelling and arithmetic, rather go by the board, and men come through these schools

*Michigan College of Mines.

with a knowledge of a little agriculture, a little physics, a little chemistry and a hundred other things, the possession of which is a detriment to them if they pursue further education; for what they did learn of these subjects in many cases must be unlearned and the time that was taken up with them was taken from the highly necessary fundamental subjects. Formerly, most of the technical schools had no English in their courses. Nothing was given in the nature of the Humanities. My days go back to when technical education in this country was still relatively new and the number of technical schools, particularly the number of the Schools of Mines was not large. I remember we divided the type of technical schools into two classes; first that which my alma mater, Columbia University, represented, and second, that which the Massachusetts Institute of Technology represents. We were taught that the technical school was a scientific school and that while the Humanities were desirable, the student should have had this training before he entered the technical institution, or if he did not have it, he should obtain it outside his technical school duties. Hence we had no time for English in the School of Mines. I believe the Massachusetts Institute of Technology has always paid considerable attention to the Humanities. This brings us to a particular question which is a vital one before this conference, namely, if Humanities are to be introduced into the course, and we have pressing on us, also many new *technical* subjects, is the time allotted to a technical education, at the present day, sufficient to properly educate a young man for an engineering career? In this connection I wish to present the paper of Prof. Robert Peele of Columbia University. He requests me to particularly say that in this paper he expresses his personal views, only, and not the official views of his institution.

PROF. PEELE'S PAPER is read by the Chairman. (See page 58.)

DEAN WALKER: I want to comment on Prof. Peele's discussion on some of the problems that are confronting us. Some of us feel it very keenly, especially his conclusion as to the length of the course. For over 20 years I have been connected with institutions where a 4-year course in mining has been offered. I have been fortunate, and unfortunate enough during the last 10 years to go through the throes of a complete revision of mining engineering, and am now confronted with a similar proposition. I think we should all follow the practice (and the institution I am now connected with still continues that practice) of giving the young man studying engineering choice as to options which he will take—a geological option, mining option or something of that kind. As to the disapproval of that practice, I have found in many cases he had no choice in the matter. A committee has now been appointed to revise the entire mining course. It has advanced

in its work sufficiently far so I feel before the end of the year we shall have no options in our 4-year course, but we are going to try to do nothing but lay the foundations strongly for mining engineering. We feel, however, as Prof. Peele feels that 4 years is not sufficient to give a young man the training he ought to have. In order that we may at least in part adopt the recommendation of Prof. Peele we are going to lay particular emphasis on the fifth-year engineering course. We are going to do all we can to induce our young men to take the fifth year. Eventually it may be that we would give no degree at the end of the fourth year. I cannot tell how it is going to work out, but that is what we are going to do. As to Prof. Peele's statement that so many engineering graduates fail to succeed after graduation, it would seem to us that that is largely our fault. It is largely the fault of the engineering colleges. You can take some catalogues, soliciting graduates of engineering colleges and check over their present employment and find they are engaged in lines utterly foreign to those they started out with.

DEAN BUTLER*: I agree with Dean Walker that the administrative officers of engineering schools are largely to blame for the fact that a considerable proportion of the graduates engaged after graduation in lines of activity foreign to the course they pursued in college. I have found that a large proportion of our freshmen have very little idea why they are studying engineering, and especially why they select that particular branch of engineering which they pursue in college. In many cases they have no more reason for so doing than they would have if the choice were based on a throw of dice. They rarely know exactly why they are pursuing a certain course when they come to us, and seem to have chosen their life work more or less at random. It appears to me that it is obligatory upon us to do something to help these young men. We should familiarize them with the qualifications that are required for success in all branches of engineering, and the peculiar qualities demanded in each separate branch. We should endeavor to acquaint them with the nature of the work they will probably be called upon to do immediately after graduation, and the opportunities for advancement open to them. We should impress upon them the fact that it is foolish for them to continue in the course that they have selected unless they are sure that they are going to enjoy the work and will be fairly well satisfied with the remuneration they will probably receive. The information given should be as accurate and conservative as it is possible to make it, and the difficulties and drawbacks inherent in each branch of engineering should not be minimized.

At the University of Arizona we have been endeavoring during the past two or three years to acquaint the young men with the

*University of Arizona.

facts mentioned through our so-called Freshmen Orientation Course which consists of one lecture a week throughout the Freshman year. Attendance is obligatory upon all engineering freshmen, but no credit is given for the course. After my first lecture this year in which I emphasized strongly the fundamental qualifications, required for success in engineering, five young men expressed a desire to be transferred to other courses. I was mighty glad to have them make the decision then, for our purpose throughout the course is to get rid of the men who should not be there, and to graduate no one who is not perfectly satisfied that he knows exactly what kind of work he is to be called upon to do after graduation, that he is going to enjoy that work, and that he has the fundamental qualifications for success in that work. If the results secured by our course are any criterion of its usefulness, I am sure that the idea deserves the consideration of all engineering admininstrators.

PROF. WALKER*: Professor Peele states in his paper that the engineering school where a six-year course is now given is a graduate school. I know he did not mean this to read that way. The school he refers to is not a graduate school, as a degree is not one of the requirements for admission. Work which can be obtained in college only is required for admission and this work can be completed in three years, in college, but a candidate is not required to have a degree.

We have been much interested in what Professor Peele says in regard to the mortality of engineers after graduation, meaning that such a large number of men who study mining engineering do not follow that profession. I think that in all our engineering schools a large percentage of the graduates will wander from the mining engineering profession and take up other vocations. This shows that a general mining engineering education is useful as a foundation for almost anything. In the school just mentioned and which is referred to especially by Professor Peele, in his paper, the work is so laid out that a man who has a sufficient amount of interest in mining engineering to complete his course will undoubtedly follow this profession after graduation. This is the case in law and in medicine.

Professor Peele distinctly states that four years is not long enough. In other words, it does not give a sufficient amount of time to properly educate a man to enter the mining engineering profession. The faculties of a number of institutions evidently are of the same opinion as in several of our prominent schools, five years' study are required before granting the professional degree, and in two others six years are required. At Columbia University, in New York, they decided a few years ago to institute a course which would require six years' study after a man left the prepara-

*Columbia University, New York.

tory school before he could receive his professional degree. This course was framed with the idea of giving the man a thorough training in the fundamentals of engineering, mathematics, chemistry and physics prior to entering the engineering school, it being arranged so that this work could be completed in three years. He then enters the professional school and devotes three years to strictly engineering subjects at the end of which period he receives his degree.

If this man takes his preliminary work in Columbia College, then enters the engineering school and spends one year there he will receive his bachelor's degree, having up to that time received what in other institutions is called a "strictly scientific education," of a high standard. He may leave then and enter the engineering profession or take up something else in which he will find this education to be of valuable assistance. If, however, the man continues through six years and receives his engineering degree he will be very thoroughly prepared in all fundamentals and, as far as is possible, in strictly engineering subjects. He will have had more time to absorb engineering instruction and is more likely to continue on in the profession.

I am very glad to have had a chance to say a few words about our aims at Columbia as I know that the present program in the School of Mines has been rather severely criticised. While some of the details of this plan may have to be changed as time goes on, we believe that the experiment is well worth while.

MR. GREENSFELDER*: I am attending these meetings to find out if possible how we as manufacturers can better cooperate with educational institutions in educating engineering students on the subject of explosives and their uses. We feel that possibly there is not sufficient time in the curriculum for the regular instructors to devote their time to that, but we are willing to cooperate in whatever way we can to provide this information. Last summer I was traveling to deliver lectures at various colleges, and I found considerable interest among the students, particularly when they listened to a man who was connected with a company manufacturing the particular product they used. One of the professors wrote me afterwards that they showed greater interest because a man coming from a company who was making the product lectured to them, than if the information had been imparted by their regular instructor.

We want to know just how we can further this idea. We would be willing to get up publications and pamphlets particularly designed for students at engineering colleges. We encourage members of our company to contribute articles to publications issued by engineering schools—in other words, our desire is to disseminate

*Hercules Powder Company.

all the information we can to students, and I want this conference to know we are open for suggestions along this line.

MR. FULTON: Mr. Greensfelder represents the Hercules Powder Company which takes the product of the technical school. Sometimes, as Prof. Peele said in his paper, there is a difference of opinion between those who teach and those who take the product of the teaching and I believe, to express myself frankly from out of my own experience, that the usual view of the company that takes the product is somewhat narrow and applied to their own particular field. For example, in a large industrial city where I was formerly connected with a prominent technical school, we asked for suggestions from the manufacturers in different fields as to what we should teach, in order to prepare men for their work in engineering. The response almost invariably was that we should train the men for the respondent's own particular business. Of course when you hear this reply from one man it sounds very reasonable but when you collect the data of the hundred replies you at once perceive how utterly impossible it is to base an education on these concrete replies. We most heartily welcome what Mr. Greensfelder has offered us, but the question remains after all "What is the best training for industrial work?" Is it general training in fundamentals and the technical essentials followed by an apprenticeship? Some of the great mining and metallurgical companies have apprentice schools. They are willing to take a technical graduate and keep him a year or two to learn their particular business. I think this method a sound one.

DEAN MOORE*: (Discussing Prof. Walker's suggestions) I think, however, there is a different viewpoint to be taken, depending somewhat upon the nature of the institution with which you are connected. In the state institutions we get a little different type of student from that in the privately endowed institutions. I found, for example, that the men who come to our institution are in many cases poor men financially, and they find it very difficult to finance four years in college, and yet some of these men are excellent men and it would be a mistake for all of us to adopt a six-year course. I believe the University of Pittsburgh has recently adopted a five-year course in mining which will go into effect next year. I think it is a question of the greatest good to the greatest number and our object in education should be to educate as great a number as possible to as high a level as is practical. In fact we have to strike a happy medium until such time as we can get men educated so the mining men as a whole will be in a position to send their sons to college. For that reason I think it will be essential for us to stick to a four-year course for some time to come.

I think also a great deal depends on the instructor. Some put men through four years who never make a failure. Other instruc-

*Pennsylvania State College.

tors will keep a man for seven or eight years and never enthuse him with the subject at all. One thing I endeavor to impress upon our faculty is to put a student in the same place in college as if he were out in the industry—getting work out of a man and getting things done is what counts. I think after all the essentials in an engineer are not necessarily more than an average ability but application of knowledge, and if you can get him to apply himself he will be successful.

Now as to vocational guidance, I am convinced there is not a great deal to it. I do not believe there is any one man, a Dean of Men, for example, who knows everything, and can advise students on any type of course. Men have come to us who know nothing about mining, yet after they have gone through the course, have been very successful. It is essential that you should give a man an opportunity to see a mine or a steel plant and see if he is willing to stick around one when he gets out. If he is going to be happier in Liberal Arts, by all means let him go through that course, but remembering this, it is a whole lot easier for an engineer to take up another line of business than for a man who has gone through Liberal Arts work to go out and take up an engineering profession. We can steer a great many of our men into certain phases of the industry, not strictly engineering, but requiring an engineering course as a foundation. I am inclined to think that in this day specializing is practically necessary to separate in the upper year or two courses in mining and metallurgy in order that students may get some of the later developments in such fields as metallography.

MR. GREENSFELDER: One of our directors made the statement that in his opinion our salesmen should be 75% efficient as service men. Where a sale involved an actual demonstration, the salesman is of greater value to the company if he is able to handle the service work himself. I do not know that I can answer Dr. Fulton's question about just what a manufacturer would recommend to educators in training engineering students. That is something that would have to be given considerable thought. An engineering knowledge will be of immense advantage to a man in following the commercial end of the business with a manufacturer of technical products. If I were hiring salesmen for our work I would prefer mining engineers as I think they would be more versatile and better suited for the service part of our work. We want to encourage students to take an interest in explosives and the proper method of using them.

DEAN BUTLER: I believe that most of my staff agree that it is unwise of us to demand of all engineering students that they pursue a course of more than four years' duration. We are all convinced that we must lay a very thorough groundwork in the fundamental sciences, and that beyond that our function is to

train the student to think, and to show him how to use the knowledge that he has acquired and which has been made available through the work of others. Apparatus and methods in vogue now are apt to be out of date by the time the student has graduated, and it is largely a waste of time to place much emphasis on such matters, especially details. A great deal of information has been printed and is readily available along almost any specialized line that the student may be called upon to follow after graduation, and he should be taught how to find and use this data, and encouraged to depend upon his own efforts to secure a working, detailed knowledge of any technical subject.

We have practically decided at the University of Arizona to eliminate all options during our four-year undergraduate course leading to the degree of Bachelor of Science in Mining Engineering, and to offer no opportunity for specialization until after the Bachelor's degree has been secured. We have reached this decision because we find that only a comparatively small percentage of our graduates follow the particular line of work (mining engineering, metallurgy, or geology) in which they specialize during their senior year, and we have also learned that it is difficult or impossible to give sufficiently thorough training in the fundamental subjects in four years if we permit our students to specialize in any way. I believe that next year we shall follow the plan mentioned, and shall offer a fifth year which, if successfully completed, will lead to the degree of Engineer of Mines, Metallurgical Engineer, or Mining Geologist. We may also decide to offer a fifth-year course in Mine Administration which will lead to a suitable degree. While it will thus be possible for our students to secure a degree in four years, especially promising men will be urged to take a fifth year either immediately after finishing the four-year course, or, preferably, after they have been out of college for a year or two.

PROF. HAYWARD: I agree with nearly everything Professor Peele has said except his conclusion. I wish, however, to comment on his criticism of laboratory work. I agree with him that if we merely make the student go through a lot of mechanical operations the time is wasted. The purpose of the laboratory, and I refer specially to a metallurgical laboratory, is to make clear the theory we teach in the class room. With the small apparatus it is necessary to use, it is of course impossible to teach practice, but we have demonstrated again and again that if a student does not get the laboratory work he is very likely to lose much that is valuable in the classroom. Our laboratory time if cut to a minimum. We stop when we think we have illustrated the theory. For instance, in running our laboratory blast furnace the campaign lasts sixteen hours, the class working in four shifts of four hours each. The men move from position to position and during a shift each weighs and feeds a few charges, taps the furnace, etc., and

takes necessary observations for a complete thermal balance of the furnace, viz., gas analyses, and temperatures, cooling water temperature and volume, blast temperature, volume, pressure, and humidity, slag temperature, etc. The day after the run all products are weighed and sampled. The necessary analyses and calculations are made by an assistant and each student is furnished with a complete account of stock and thermal balance which are discussed in detail at a conference session of the class. During the campaign about five tons of charge are smelted and our experience has proved that the time and money are well spent.

I should like to give some laboratory experience which proved unsatisfactory and tell how I remedied it. Two years ago in a readjustment of the course in Metallurgy some additional time was made available for laboratory work. This was to be principally in copper leaching and I laid out a series of tests on sulphatizing and chloridizing some copper ore, leaching it hot and cold with various acid strengths. After the work was completed the results of the entire class were plotted and curves drawn to show the extractions under different conditions. At the last session of the term I took the figures and tried to show briefly their application in calculating commercial costs, plant capacities, etc. During the term, although the men had faithfully done the work assigned, there was no evidence of enthusiasm and very little interest. I took occasion to mention this to one of the more thoughtful members of the class and asked him what the trouble was. He told me frankly that most of the men didn't see what it was all about until the last exercise when the figures were applied. Accepting this as a just criticism I made a radical change last year. There were twenty men in the class. Four captains were chosen by the students themselves and these leaders divided the class into four groups of five. To each group I gave a separate problem of roasting and leaching and left them to divide the operations of roasting and leaching. The results obtained were to be used in calculating a plant to treat 1,000 tons per day and make estimates on operating cost, finally calculating what copper must sell for to make the plant pay under the conditions determined. I gave them suggestions and pointed out methods of attack, but they went far beyond my requirements or expectations. They wrote for catalogues, interviewed their engineering friends and sought information from every available source. Of course numerous assumptions were necessary and doubtless many of the estimates were wide of the mark, but in the end four highly creditable reports were passed in and man after man told me that he had enjoyed it more and obtained more good from it than anything he had done in his course. Every man had put in hours beyond the allotted time not because he had to but because he wanted to and I don't think one complained or expressed regret.

This experience demonstrated to me more than ever that one

of our primary functions as teachers is to implant a real thirst for knowledge in the student. If we do this the student will educate himself with only a little guidance on our part. If we can't stimulate a student's interest, no amount of effort or spoon feeding will enable us to turn out an engineer that is good for very much.

Professor Peele's conclusion was that more than four years is now necessary in a mining school. With this I disagree. There are a few cases, of course, where a man konws just what he is to do and needs special preparation for it, but on the whole it does not seem desirable. First, with careful planning is is possible to teach the fundamentals of mining or metallurgy in four years. Beyond a certain point we get to details of practice which can be better learned in the plants. Second, if the student has acquired an enthusiasm for his profession he will not cease his study after graduation, and two years after he receives his degree he will be better educated than if he remained at school. He will also be farther along in his profession. If the student hasn't become enthusiastic for his profession he is better off in practice even if he doesn't study than he would be in school. Third, the item of expense must be considered. Many have hard work financing themselves for four years. A longer time would be prohibitive.

Let us provide graduate courses for the few men who need them but keep the regular course at four years.

I am inclined to think that we could do much to stimulate study after graduation by increasing the practice of offering engineering degrees to be given after two or more years in practice to graduates who present satisfactory evidence of study and research.

PROF. SPERR: I remember a little experience I had in talking with a gentleman. I asked him "As a graduate yourself, as a teacher of mining engineering, a mine manager and an employer of much technical labor as well as other kinds of labor, I wish you would tell me what you think an undergraduate mining engineering student should be taught." He said "To think," and I believe he hit everything that is really worth while. Yes, I believe a 4-year course is long enough. Three years is long enough if you make it intense enough. We think we can put out pretty good men in three years by working them the year around and doing it intensively.

I have a great deal of respect for what Prof. Peele has given us, and what he says is true, but after all we have got to cut it off somewhere and the question of where we must cut off outside of fundamentals perhaps will have to be settled by the conditions each school is working under and what it tries to do. The objects of the different schools may be divided rather roughly into two classes: One, to make what we call professional engineers, reporters on mining properties, etc. The other is primarily to make mine

operators and managers. With us we think more largely of this latter object, and most of our men follow that line. We all agree in that the fundamentals must precede everything else and all we can do in any special line is to help the student to assimilate the fundamentals. If we do that we will do well. We cannot make them finished practitioners in any line you can mention. We can make them useful for a certain kind of work which gives them an entrance into some capacity or other and then it is up to their own individuality and the forces in them whether or not they will be successful.

MR. FULTON: It is well to sum up some of the ideas that have been expressed. How are we going to achieve the result of vitally interesting the student so that when he leaves he will possess the fundamentals and enough of technical knowledge to begin his career with? The question of a four-year or a six-year course for a mining or metallurgical education is a fundamental one. Why do we wish more time now than we did ten, fifteen, or twenty years ago? I think the answer is plain. The amount of professional knowledge has increased greatly since that time. Twenty years ago a mining engineer was also a metallurgist. Then a graduate in mining engineering might find a berth in a steel plant and very soon adapt himself perfectly to the work in hand. Now all this is changed and the technical knowledge that has accumulated makes for a sharp division between mining and metallurgy. How specialized technical knowledge relating to metallurgical operations is may be illustrated by the existence of an active technical society known as the Electrical Engineers of Iron and Steel Plants. These men are engaged in electrical engineering solely in relation with iron and steel works and of necessity must possess some general knowledge of the metallurgy of iron and steel. There is a demand for men who are thoroughly and specifically trained in either the mining branch or the metallurgical branch of the mineral industry.

I believe it incompatible with modern industry to give the student a general course only and then graduate him expecting him to find his place. He must be specifically trained in a certain direction. The question is: Will it take longer to do this now than formerly? Is four years enough or does it now require six years? Will we expect to make it eight years a decade hence? Solving the difficulty by lengthening the time is, I believe, the easiest way which is not necessarily the best way. The difficulty is fundamental and I believe cannot be solved by an addition of time. It really rests in the psychology of the student. In general the young man between 18 and 23 in the technical school or the university has usually only a hazy idea of what he is eventually going to do. I have a low opinion of the practicability of vocational guidance. In nearly all cases, the direction in education that a young man

takes is at the suggestion of his parents or interested friends and is not his own free choice. There are, of course, some men mature enough to make a free choice but the majority are not of this type. Broadly I believe it is undesirable to attempt to direct a man vocationally. In most cases those who find themselves out of place in the technical school will seek an adjustment. It is also true that the man educated in engineering has such a generally useful education that he can readily enter business or almost any industry and succeed. The student is in college or technical school at a critical age, psychically. I believe it is more difficult for a young man to concentrate on work in hand between the ages of 18 and 23 than at any other time in life. His chief interest during this period is in the opposite sex and it needs discipline and admonition, constantly applied to keep him at work. This rests in the nature of things and needs no further discussion except that it is one of the things, though well known, frequently ignored. At 23 the man's viewpoint radically changes and he is desirous to begin work. Moreover, he is not content to work just to be educated, but he wishes to do things in his profession, his objective becomes definite. I have always felt that in engineering the fundamental conception of the profession and the orientation of the individual are obtained only in the works and in the field. In this respect it differs from the professions of medicine and the law, as for example, in modern medical education the student is in close touch in the latter years of his course with practitioners through the clinics and the hospitals. The engineer deals with labor and recently the demand is voiced to instruct the student in what has been termed "human engineering." But can this be taught in school? Fundamental conceptions can be conveyed in courses of economics and sociology but the real understanding and practice can be gained only in the works. I believe, therefore, that four years in the technical school are enough to teach the man the fundamental sciences and to direct him technically in a basic way in the particular field he expects to follow. His orientation and the instruction in the technique of his profession is well left to what may be called his apprentice course in the mine or works. I have the highest regard and veneration for the Humanities, and a man's life would, indeed, be passed in gloom and darkness were it not lighted by what is so beautiful in science, art and literature. But with the exception of English Literature, the great field of the Humanities can only be indicated to the student and reliance must be placed on his initiative and curiosity to explore this region that will yield him such full treasure for the enjoyment of life.

PROF. WALKER: We all undoubtedly believe that specialization in several subjects is impossible. We have a certain amount of ground to cover and a comparatively short time to cover it in. As a result it is impossible to instruct students very thoroughly

in more than one branch of engineering. In designing a course for a mining engineering student we must necessarily include work in electrical, mechanical, and civil engineering, but we cannot attempt to make electrical, mechanical or civil engineers out of these men.

It requires considerable work to keep our courses of instruction abreast of the times and while our Chairman has had a much longer experience in teaching than I have had, in spite of the fact that he was graduated from the Columbia School of Mines a number of years after I was, I can not agree with him in the statement that there is but little more to teach now than at the time either of us was in school. Many subjects not even thought of then must receive a great deal of attention now.

While I believe fully that the instruction in the fundamentals should be thorough I also believe that we must have time to give proper instruction in engineering subjects afterwards in order that thoroughly trained engineers may be produced. For your information I would like to state that in the School of Mines at Columbia the students may select either mining engineering, mining geology or metallurgical engineering and specialize in one of these three branches during the last two years of their course.

CONFERENCE HELD WEDNESDAY, OCTOBER 19, 1921.

MR. FULTON: We will open the second afternoon of our conference with remarks by President O'Harra of the South Dakota School of Mines. He began yesterday to say something to us about what he thought should be in the mining course. When Dr. O'Harra concludes, it will be desirable to plan for a continuation of our organization for next year, and I wish to state briefly that the matter presents itself to me in this way: The American Institute of Mining Engineers has claims on this conference. I understand that when Mr. C. H. Mathewson was requested to address this conference on metallurgical education he said that the subject of mining education belonged to the American Institute of Mining and Metallurgical Engineers. That, of course, is a matter open to discussion. It would appear that we might be submerged in the Institute as its activities are so large and varied. I doubt whether under its auspices we could come together as closely as we do here. The title of this organization is "Committee on Education and Public Service" and as stated yesterday this is a very comprehensive one. In this organization I believe the mining schools and the mining and metallurgical departments of the Universities throughout the country may very well get together and meet for the discussion of their problems. I think it is unnecessary for this organization to set a very high aim, such as an all around reform in technical education; meetings for discussion and exchange of ideas will be ample motive. Miners and metallurgists and geologists have always held together the world over, and the field, while a large one, is not so large as to preclude organization into one group. If we lay the foundation for such an organization at this meeting, and include the mine inspectors and the state geologists and divide the group into two divisions—first: those having to do with mining education and second: those having to do with public service, I believe we will have something well worth while. This can be done under the auspices of the American Mining Congress. The Society for the Promotion of Engineering Education might perhaps be considered as the proper place for the educational division, but this Society has been in existence so long and no one has taken any particular interest in getting the men interested in mining and metallurgical education together, so that the Mining Congress seems to afford the better home. I now call on Dr. O'Harra.

DR. O'HARRA*: Mr. Chairman and Gentlemen: Dr. Fulton has just informed me that my name is on the program but I was not aware of this fact and I do not know where I shall begin this afternoon. It occurs to me that it is clear to all of us, and

*South Dakota State School of Mines.

particularly after what was said yesterday afternoon, that we have two unreconcilable things with which to deal. We have a limited amount of time available and an unlimited number of subjects, it seems to me that it behooves us to recognize this freely and fully and try to adapt ourselves to the situation. We cannot forever be allowing the individual instructor to select his favored subjects and we cannot forever try to get into a course everything that may be legitimately allowed in it.

I am of the belief that we should first group our thoughts around the four year course. After this is definitely done and after we have worked out this problem in the best way we can, then I believe we should try to work out something in the way of a fifth year. After this, as indicated yesterday, I think some thoroughly well equipped institution or institutions ought to work out something in a definite detailed way more extensive even than the fifth year course. We at the South Dakota State School of Mines are not at present so much interested in the sixth year but I do feel that there is an opportunity for some institution to develop in good way this particular feature.

Now in regard to what should be in the four year course. We all say earnestly and unanimously that adequate attention should be given to fundamentals but no two men will agree as to what all the fundamentals are or how much of the fundamentals should be included. A considerable percentage of students when they come to a technical school lack thorough grounding in mathematics. Mathematics is certainly fundamental and the question arises at once how much mathematics must a man have in order to do good engineering work. He will find differences of opinion right there. I recently talked with a gentleman who has had long and successful experience in metallurgy who indicated to me that he seldom or never uses calculus. Some metallurgists would, I fear, think him peculiar, but the question arises nevertheless, whether it is an absolute necessity for every man to have a thorough grounding in calculus. Mathematicians will perhaps say that it is necessary, and not subject to question. Personally, I believe it possible, in view of the many shortcut mathematical helps now available, for an individual to be a good mining man without very much calculus and particularly do I think this true regarding metallurgical men but I am of the belief that all things considered, both the mining engineer and the metallurgical engineer will be better prepared for his work if he has a thorough grounding in calculus and at the South Dakota State School of Mines this subject (differential and integral) is required of both.

A man must have training in chemistry, the amount depending somewhat on whether he is to enter the mining field or the metallurgical field. The mining man should have at least the elements of chemistry and if possible some special work in qualitative and

quantitative anaysis. The man who is to enter the metallurgical field should have all the chemistry he can get. I say this with a good deal of seriousness. He cannot get too much but an institution can try to give him too much in four years. One must have physics. I suppose we may say here, as elsewhere, the more the better, but we must stop somewhere and the amount must be governed to a considerable extent by the series of subjects taken along with it.

Perhaps it is not out of the way to say that my particular field is geology. In the institution with which I am connected we for a considerable number of years devoted four years to geology. We gave general geology in the freshman year; general mineralogy, including crystallography and blow-pipe analysis in the sophomore year; metamorphic geology including petrography in the junior year and economic geology in the senior year. I had the course arranged that way, particularly, I suppose, because I am a geologist and because my co-workers were willing to let me put it in, but in recent years we have felt that there should be some change. In view of the fact, as I believe, that the heads of the various departments are under necessity of considering the matter largely a game of give and take I consented to lessen the requirement and at the present time we are giving general geology in the sophomore year, mineralogy in the junior year and economic geology in the senior year. I may say that we have added a fifth year to both the mining and metallurgical courses but this fifth year is not a requirement for the first degree. Its completion entitles the graduate student to the advanced degree. In this fifth year we give the geological work, which was formerly given in the junior year, namely metamorphic geology. This is ordinarily considered a very difficult subject and, as it is taught with us in a very thorough way, the fifth year students are better able to handle it.

In a recent revision of our courses we, to some extent, rearranged our English courses. We require one year of English, the freshman year, and have arranged for electives in the sophomore and junior years. The sophomore work has largely to do with engineering or scientific matters and is so arranged as to bring out to the best advantage the intrinsic value of the subjects studied. The junior work includes especially techical composition. We have for some time taught and now require a year's work in economics. This is taken by juniors. Sociology is elective for juniors and seniors. In addition to this we have recently introduced courses in connection with the business essentials of engineering, including particularly a consideration of the underlying principles of organization and management. This is usually given in the senior year. We feel that the engineer has not in the past had enough business training. The instruction does not have to do with book-keeping or simple accounting but rather to the larger

features of the business with which the manager of an organization has to deal. We have no special requirement in connection with the training of students in the looking up of scientific or technical literature but indirectly we emphasize the importance of the matter.

Now I think that at the South Dakota State School of Mines we have pretty fairly solved the difficulty of requirements in so far as concerns the four year courses. Briefly we require all of our mining and metallurgical students to take mathematics through calculus. We give calculus four hours the first semester and four hours the second semester. I believe this is doing as well as one can reasonably hope for in a four year course. We require physics—one full year of general physics, and it is a good stiff course. We require of mining students two years of chemistry in addition to the one year required for entrance, and three years for the metallurgical students and most of our students take what practically amounts to four years—this in addition to the distinctive metallurgical courses.

The two greatest difficulties we have had to contend with are these—how to give the student some work in modern languages, particularly French and Spanish, and how to give some work in certain subjects related in a way but in addition to the sciences required. Personally I think, and I think very seriously in regard to this, that institutions generally over the country today have not awakened to the opportunities and to the advisability of teaching some of the most fundamental things in connection with the biological sciences. I believe that if there is to be any revision of our mining and metallurgical courses there should be some real, good, honest study made as to whether or not it might be possible to introduce to the student some of the more important phases of biological knowledge. You may think this strange and that so far as engineering work is concerned the engineer has no particular use for anything of this kind. We yesterday discussed the cultural needs of men going through our institutions. I think that one of the most helpful cultural subjects that can be devised can be made up of certain phases of geology or certain phases of biology. When I was in college I took five and one-half years of Latin, three and one-half years of Greek, some German, some French, some Anglo-Saxon, and about all the English, literature, and history I could get—more than the catalog required and more mathematics than was required. My friends, I mention what I had in college because I do not want you to think that I speak from lack of knowledge of the studies, which to many minds, are the cultural subjects par excellence. Some of the best opportunities for cultural work are in connection with things far removed from the subjects I have named. It is after all not so much what we teach as how we teach it. If we cannot get cultural things into a course let us teach

some of these things without getting them into the course. I just want to drop a thought in regard to this. If we do not teach some things that are not in the curriculum we are missing a wonderfully good opportunity and personally I fear that we fail to recognize our absolute duty.

In my judgment mining and metallurgical men should not go out from an educational institution unless they know something of the fundamental things of life whether it be biology, sociology, or something else. The engineer must know something besides the mere technic of solving physical and chemical problems. He must know something of what life means and when we cannot put all of the valuable cultural things into courses let us see to it that we get some of them in. After all one needs to use ingenuity if he attains success.

I do not know that I have anything further to say on the subject of the four-year course. In my judgment the four-year course is all right but I am partial to the alternate of a five-year course. The four-year course is not enough but it is as much as some men can take. In many cases there is good opportunity for the fifth year. We introduced it, other institutions have introduced it. Now, if we are going to have a sixth year, let us have it in all the best that the term implies but when we have wrought out the six-year course let us not forget the good things available in the five-year course and, likewise, let us not overlook the good opportunities of the four-year course.

MR. FULTON: I believe Dr. O'Harra struck a key-note in his address; when he dwells on the importance of the sciences particularly of the natural sciences in our higher education. He has expressed the scientist's view of education. Herbert Spencer and Thomas Huxley expressed fundamental ideas on this subject and I firmly believe that the day is coming when most educators will view education from this standpoint. Certainly it is true that no educated man should go forth from a university or school today without some fundamental knowledge of the biological sciences. I distinctly remember zoology and botany in my college course but these subjects have disappeared as unnecessary for the engineer.

I agree with Dr. O'Harra when he states that if subjects are to be added to the engineering course they should be of this type rather than the purely technical subjects. These are the subjects which are pressing for entrance. Can we take the responsibility as educators of engineers and let our men go out without a fundamental knowledge of such subjects as economics, biology, and sociology. There is a tendency in some of the technical schools to make instruction more and more practical, so called. I believe this tendency a great mistake resulting in not much more than a trade school education. I believe that the acceptance of the sciences as cultural subjects and the recognition of the great

possibilities of biologic science and psychology in ameliorating human life will come rapidly within the next 5 or 10 years, and those of us engaged in education should be prepared to aid in the change.

PROF. SPERR: In regard to the many interesting questions under the Symposium on Mining Education which was sent out by our Chairman, Dr. Fulton, in preparation for this Conference, I would say that it would seem to me well to discuss all of these questions exhaustively if we were allowed sufficient time. I have made a few notes on some of the questions as follows:

1. What is the scope and content of a modern course in Mining or Metallurgy?

Upon the answer to this question there can be no precise agreement among educators. The following outline is suggested as a basis for discussion. The number of hours is given as the total time to be devoted to the subject by the student.

	Hours.
Mathematics as far as the calculus	600
Physics—Mechanics, Heat, Light, Magnetism and Electricity	300
Chemistry—Theoretical, Qualitative, and Quantitative including Assaying	900
Geology and Mineralogy	500
Lettering and Drawing	350
Language	250
Wood and Iron Working—Shops	400
Surveying—Field and Mine	750
Materials and Mechanics	800
Hydraulics	150
Electricity	200
Economics, Industrial Accounting and Management	250
Mining Operations, or Metallurgical Operations	600
Plant Design—Either Mining or Metallurgical	200
Total number of hours definitely specified	6,200
Specialized work in any one or more of the above subjects as may seem desirable, including calculus if desired	1,000
Total numbers of hours of undergraduate work	7,200

2. Can the Co-operative System in Engineering as Practiced by the University of Cincinnati be Successfully Applied in a Mining or Metallurgical Education?

Yes, where the surrounding conditions are favorable; and no, where they are unfavorable. At the University of Cincinnati they justly emphasize the importance to the student of learning labor conditions. Many of our students work more or less in the mines, mills and smelters during their college career. Such work is not

required for graduation and no credit is given for it towards a degree. For many years we have had the question of requiring such work under consideration. Under our present system the student who works in the mine finds his job like any other laborer and is taken into the confidence of his fellow workmen in a way which would not be open to him if he were placed in his position under the other system, and we think this gives him the greatest possible advantage for learning the laborer. We advise our students to work in the mines to learn mining and, above all, to learn miners and to learn them sympathetically—in other words, to study the human element. The good driver loves his horse, and the good superintendent loves his men. Good superintendents, good bosses, are born, improved by proper training, but not made to order. We are not yet convinced that we should adopt the other system.

3. What is the Best Way to Make Room in a Mining or Metallurgical Course for the Constantly Increasing Number of Technical Subjects which Apparently Should be Included?

No doubt there is yet much room in most of these courses as actually given for the introduction of new technical matter for illustrative purposes, even in the teaching of the so-called fundamentals. When everything possible has been thus provided for, old matter will have to give way for the new whenever the new is shown to be the more important.

4. What are the Basic Elements of a Mining and Metallurgical Course? Answer, Mathematics, Physics and Chemistry.

5. Should the Mining and Metallurgical Course be Recast and Rebuilt and if so on What Basis? Answer, yes, constantly, and on the basis of improvement for greater efficiency.

6. Are Four Years Enough for a Course in Mining or Metallurgy, Taking into Consideration all Elements that Enter into this Problem? This question was quite thoroughly discussed in our conference the other day.

7. How is the Subject Best Taught? Answer, by requiring the reading of certain selected lessons and the solving of definitely assigned problems. The aid of models is helpful, visiting mines is essential, work in laboratories is important, and work in mines is desirable.

8. How is the Subject of Metallurgy Best Taught? Answer, in very much the same way as the subject of mining, except that metallurgical and milling plants and subjects are to be substituted for mines and mining subjects.

9. How Much Mathematics Should there be in the Mining Course? In the Metallurgical Course? See outline under the first question.

10. What is the Best Way of Teaching English to Engineering Students? Answer, first by arousing their interest, showing them

the value of being able to handle the language properly and efficiently as one of the necessary means of accomplishment; Second, by requiring the students to speak and write for the teacher's commendation and criticism. The speaking may be in class or in conference discussions and recitations. The writing may be on topics of the students' own choosing.

11. Should the English for Engineering Students be Technical and Limited in Character or Broad and Include Literature? Answer, the use of good English depends on neither.

DEAN BUTLER: I think as scientists or engineers we are apt to believe that uniformity of system is very desirable. I know we feel that way in regard to much of our work, and I used to have the same idea relative to engineering courses; but I am not so sure now that it is desirable for us to work toward absolute uniformity in mining engineering courses. I realize that it would be impossible to achieve that end even if we did attempt to do so, for I have never found two Deans of Mining Schools who could agree in all the particulars of a curriculum. There are, in fact, many reasons why it is not desirable that all mining curricula should be identical. In every institution we have one or more instructors who are exceptionally good teachers—men who can enthuse their students, who can make them work wonderfully well, and who perhaps mix into their courses some of these other things that we have mentioned and which are not in the curriculum. Such men will naturally find it easy to gain a little extra time for their work, and will do so at the expense of other instructors, who, while they may be good, are in no way exceptional. Then, also, the needs and opportunities of the students in different mining schools vary considerably—some, for instance, are mostly interested in coal mining, while others feel little or no need to study this subject at all; some of you are in regions where iron and steel mining, ore dressing, and metallurgy, are especially important, while others of us see no reason to emphasize these subjects. It seems to me that the object of discussions of this kind is not to attain uniformity, but merely to ascertain what other people are doing and thinking, and to discuss these questions in the hope that we may be given ideas useful to us in our work. I believe, however, that it is possible and desirable to reach agreement as to how much of the fundamental sciences of mathematics, physics, chemistry, and geology we should demand, and, roughly, what the material covered in these subjects should be. I hope that in subsequent meetings a part of our time, at least, will be given to a consideration of these subjects, and that eventually we shall find ourselves in accord on such matters.

MR. FULTON: One of the interesting questions before us is that of mathematics and which was touched on by both Dr. O'Harra and Prof. Sperr. Dean Thomson of Idaho will give us a few remarks on the subject.

DEAN THOMSON*: I want to thank Dr. Fulton for saying "a few remarks" as that saves me from making an explanation as to why I have not a formal paper. First of all with regard to this question of uniformity, some of you may remember a year ago seeing a diagram showing the percentage of time devoted to the various studies which I exhibited at a meeting of the S. P. E. E. I do not think there is any danger as to uniformity. We are evidently not in any very serious situation in respect to that. The diagram does not represent all of the schools but most of the schools. I am sorry to find friend Butler's school omitted. We leave out Columbia because they are on a different plan or basis, but this diagram is based upon the ordinary four years' course. Note a variation in the subjects as given, mining and metallurgical engineering, geology, chemistry, physics, mathematics, economics surveying, drawing, etc. Evidently we are a long way from uniformity in those things, and I am inclined to think it is probably just as well to stay away from uniformity. Strong men will emphasize their work and it is highly desirable that the students should have the advantage of it. If you have a weak man naturally his work will be minimized.

Notice the variation in mathematics. There is variation from a minimum of perhaps 5% to a maximum of about 15%. What we tried to do was to take the catalogs and work from those. By careful work we managed to get things down to a fairly uniform basis of comparison.

Now specifically with respect to the question of mathematics, I imagine I am probably on the opposite side of the question from most of you. Personally I think if we are to let mathematics stand upon the mental discipline ground, it cannot stand there very long. Its position in that field is exactly the position Latin or Greek occupied 30 or 40 years ago, and I do not think such a position can be held much longer. I know there are a good many teachers of the older school, particularly teachers of mathematics who cling to that idea that if one only had a stronger mathematical training he could master anything, but most of us know from personal experience that there is no necessary correlation between mathematical ability and any other kind of ability either in teachers or in students. As to its cultural value I would like to have someone enunciate just what is "cultural education." Mathematics has never been listed as among the fine arts of life and I do not think it can stand very long on the basis of its value in conversation or "pink teas" or anything of that kind.

Let us turn now to the question of its utilitarian value—the answer to this question is to be furnished by the examination of the literature of the profession. One can search the transactions

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of the Institute, the files of the Mining & Scientific Press, or the Engineering & Mining Journal for a differential or an integral sign practically in vain. In our standard text books the same thing is true. Take our chairman's excellent work "The Principles of Metallurgy." Dr. Fulton (addressing the chair) "how many integral signs are there in that book?" Dr. Fulton, "One I think, but I didn't put it there" (Laughter). Evidently the application of higher mathematics to Mining and Metallurgy is not extensive.

So much then for the application of mathematics in the work of the profession. Nevertheless I believe in spite of all that we ought to have a good proportion of mathematical training in the mining engineering course. I believe, however, that it will have to rest entirely upon the utilitarian basis on the ground that there is just as much training in the study of a thing which is useful as in the study of a thing that is useless. I believe that our mathematics has got to rest fundamentally upon the utilitarian basis, and I believe that our mathematics should be taught with its practical application constantly in mind, not a narrow, limited practical application of the thing, but with a view of its broad general use. I believe there is a great deal of material in the average traditional course in mathematics which has no relation in Heaven or on earth to that with which the engineer has to deal and which could be excluded from the course with very great profit, and I would like here to refer to the really remarkable work being done by Prof. C. C. Moore, at the University of Washington—Moore is taking one or two sections of freshman engineers and putting them to work on problems in engineering mechanics teaching them the mathematics they need, as the need arises in the solution of problems. The result as I can certify from evidence afforded by the students themselves is that by the end of the year they are solving problems not usually reached until the end of the Junior year. Another point is that these men, who by the way still continue the traditional mathematics courses, show an ability in the calculus courses which the other men never attain.

MR. FULTON: You have heard Dean Thomson's remarks on mathematics. I recall we had a paper last year by Prof. Peele on this subject. There was considerable discussion at the time. I believe that the question of mathematics is dual. First, mathematics we might say is a cultural subject or a subject which is in the course for the purpose of developing the reasoning power, and second it is a utilitarian subject, and furnishes one of the tools of the profession. I know from personal experience in teaching that students who have gone through this long training in mathematics come to a subject in which mathematics might be used and then lamentably fail to do so. There seems to be no connection in their minds with the subject in hand and their training in mathematics. I cite a metallurgical example. There is a problem in alloys in

which we desire to calculate the amounts of the several constituents which are present. The calculation is one of proportion. You give the students this problem and usually at the first, not more than one in 40 or 50 can solve it and arrive at the correct answer. There seems to be no connection in the student's mind between the principles of mathematics which apply to the problem and the problem itself. I have noted this in detail year after year to discover whether I perhaps was hasty in my judgment but it invariably comes out the same way. The student is studying alloys and hence a problem in metallurgy—but in reality it is not a problem in metallurgy but a simple problem in mathematics. The connection is not established in the mind—not even with the best of men. Now, naturally this is not true only of alloys or metallurgy but of all other courses in which mathematics is used. From the standpoint of utilitarian value in a course of mining or metallurgical engineering, I think mathematics is more or less of a failure, so far. There is another point concerning mathematics. Those of us who have the "mathematical mind" (some of us have, some have not) know that the mathematician must be precise and specific in his start of a mathematical theorem. But in purely mining and metallurgical problems, in order to complete mathematical formula, one must *assume* certain things. One cannot carry out the calculations without doing that and of course the result of a mathematical calculation which is based on an assumption is either correct or incorrect, as the assumption is. There is no question but what the civil engineer, the mechanical engineer, and the electrical engineer deal with mathematics in quite a different way and what I have said does not apply to them. As regards the mind training obtained by mathematics, I am frank to say that I used to be a believer of the old school, but doubts are now creeping into my mind. There are so many men who go through mathematics in a mechanical way. One can learn mathematics in a mechanical way. If you do not comprehend the problem you go to someone for help—that help is rendered you and the helper does the real mathematical thinking while you follow the routine calculation. The mathematics in the case is done for you. By such means men get through their mathematics some way. But how much mathematics they know at the end of the course is a question and I do not hesitate to say that the utilitarian value of the mathematics acquired in this way is but small. Mathematics to a certain extent are essential in the study of physics and chemistry—just how much is necessary I do not know but I am beginning to doubt the educational value of mathematics carried *too* far and it is an open question as to whether some of it might not be eliminated and replaced by other things.

PROF. SPERR: I am radical on that subject. It is not the fault of the student but it is the fault of the teacher if beneficial

results are not attained from the study of mathematics. Mathematics is both utilitarian and beneficial for mental development if properly taught. It develops the analytical capacity of the brain, and I do not think any of you will contend that the mining engineer requires no analytical capacity. He needs to know how to take the known quantities and from those known quantities to find the value of the unknown, analytically.

PROF. WALKER: My object in coming to this meeting was more to learn the opinions of others than to express an opinion myself. I find that I have expressed one or two opinions already, and, on the subject of mathematics, would like to say another word. In our six-year course we devote a considerable amount of time to mathematics, some may think too much. Our work in this subject is so arranged, however, that while the students are taking the calculus they are applying the principles of calculus in their work in mechanics and physics, so as the men are taught their mathematics they are instructed how this training can be utilized. In other words, we consider mathematics not simply a training for the student's mind but a subject which can be utilized in his daily work.

It would seem to me impossible to leave the calculus out of a well designed engineering course, as otherwise how is a man to thoroughly understand his mechanics, physics, or resistance of materials? In teaching students who have gone through this fundamental training I find that they are apt to use mathematics on all occasions. In fact, the use they make of higher mathematics in problem papers is sometimes embarrassing. In arranging for the course in mathematics it is well to have the teachers on this subject confer freely with the teachers in the departments of physics, mechanics, and engineering so that the best results, from an engineering standpoint, can be obtained.

DEAN WALKER: I am much like Prof. Sperr in my feelings only that I call myself a Conservative instead of a Radical. I believe that mathematics has a most important bearing on all kinds of engineers irrespective of the branch of the work in which they may be engaged. I agree that the way in which the subject is taught is of much importance, and in Kansas we probably are in better shape than are many of the schools in that several of our mathematics teachers are men who have had some experience in engineering, or who have made particular study of the application in which their students will have need of the mathematics principles that are being taught.

My opinion is that the subject is of value from both the disciplinary and utilitarian viewpoint. In its disciplinary or mental training features it is true, as Prof. Sperr says, that the power of analysis must be developed in our students if they are to progress satisfactorily in their teaching work. But it is not of this phase of

the subject that I wish to speak. I cannot see how we are to give our students the proper training in Physics and certain other allied subjects without a sound mathematical training along established lines. If we are to give our men the fundamentals of science in an adequate fashion they must be given the necessary foundation. In my opinion it is the primary function of the schools of engineering to train men in these fundamentals. Unless we are doing this the student is spending time ineffectively while he is in our schools, and we are not doing the right thing by him.

The method of teaching first formulated by Prof. Moore, then in Washington State but later in the training branch of the engineering corps of the army, has been referred to. I have had opportunity to see at short range some of this work. It gets certain results, but I cannot see how by any possibility it could be adapted in an institution that is committed to the plan of teaching sound fundamentals that are at the basis of technical education. It has some value and under certain conditions where quick results are desired along specific lines, it can be used to advantage. It is at best a tentative, not to say a makeshift, method of dealing with applications of scientific principle.

DEAN THOMSON: In the first place I want to set myself quite right with Prof. Walker and this meeting. I would not be willing at all to sacrifice the calculus. We agree there, but my point is I believe that all of our mathematicians should be given a more definite orientation in the direction of its application than is now given, and I think we can agree on that then if in doing that there remains any opportunity for a comparison it should be done. Then as to the other thing, Dean Walker of Kansas has had some first-hand experience apparently with Prof. Moore's method, but his conclusions are not the conclusions which I gather from what I can learn from the application of things at Washington. It may have been a makeshift method as applied in the army. I think everything we did in the army was of necessity makeshift or we would not have gotten anywhere, but Moore's method in college work has gone too far to be characterized as a makeshift.

PROF. HAYWARD: Along the lines of Dean Thomson's remarks, I recently was in conversation with one of our instructors in applied mechanics. I was making the complaint which I frequently make—that calculus is a splendid thing but very few students know how to use it. He agreed and went on record with this statement that one full term amounting to about 60 hours of our applied mechanics could be saved if we taught that in connection with calculus. His idea was to teach the calculus and at the same time teach the applied mechanics—that was his opinion but I do not know how general that is.

DEAN WALKER: I do not mean to condemn the method of Prof. Moore as not having any value in itself, but my point is

I cannot conceive how we could really replace a complete course in a mathematical subject.

MR. FULTON: I doubt if there is as much difference of opinion among those discussing this question as there seems to be. I feel sure that neither Dean Thomson nor myself would like to do away with mathematics. It is evident that many courses in the engineering curriculum have had a serious revision in the last 15 or 20 years. The chemistry is totally different from what it used to be; the physics is different; but mathematics is on the same basis as it has always been. Why this is I do not know but perhaps this is one reason for it: in engineering schools, as in the universities, mathematics is not usually taught by engineers. It is taught by men who have a different viewpoint of mathematics than engineers. If mathematics in schools of applied science be taught by engineering instructors we would probably obtain a different result from the utilitarian standpoint. Take the whole field of mathematics in education—starting in the grammar school where the student begins with arithmetic and then goes on to algebra, and then passes on to the high school where he again takes algebra and then geometry and from there to the technical school or university continuing the series, and certainly the facts are evidence that most of those who go through have received no direct benefit from a utilitarian standpoint within the range of the higher mathematics. This is a fact I think we must face. Dean Walker said his students bring him problems worked out by mathematics and he wonders why they used so much mathematics in working out that particular problem. I believe that mathematics is an indispensable tool for the engineer but our system often fails to furnish a good tool; in place of high-speed steel it is made of malleable iron.

CAN AN EFFICIENT COURSE IN MINING BE GIVEN IN FOUR YEARS?

Robert Peele

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This question may be considered from two viewpoints: that of the teacher in the mining schools, and that of the employer of young engineers. Both are vitally interested in the establishment of a system of training that shall be good both educationally and professionally. The student's point of view, although he may not realize it before graduation, will usually be found not greatly different from that held by the teacher.

I.

It is difficult for anyone who is not a teacher, or who at least has not been a student in a school of mines, fully to understand the pressure for time existing in almost all parts of the schedule of study. Every competent teacher of an engineering subject recognizes the impossibility of covering the ground adequately in the few hours per week at his disposal. It is a truism to say that he must first of all see to it that the students get a thorough grounding in the principles and essential features of the subject. If he fails to insure this, he has failed in his chief function as a teacher. The utmost care is necessary in framing the outline of his subject, to the end that it shall be clear, concise and logical.

But, this is not all. The dry bones of the skeleton must be clothed with flesh and life-blood infused. The personality of the teacher is of prime importance in accomplishing this. If he is fully competent, his own convictions will stand out clearly; convictions that are based on knowledge of both theory and practice. The second requisite is a judicious selection of illustrative problems and examples from practice. It is only by a combination of these two elements that the enthusiasm of the students can be aroused and their interest maintained. All of this must be compressed into the brief time allotted to each subject, for lectures, recitations and the accompanying laboratory work.

While the fundamentals of most branches rarely or never change, advances and modifications of practice oblige the teacher frequently to revise his lecture notes. The endeavor to keep abreast of the times leads to careful and anxious examination of the table of contents of each subject, for the purpose of cutting out possible non-essentials. Revision, however, rarely cures the

trouble. What the teacher is able to eliminate, is sure to be more than offset by the necessity of bringing to the attention of his class new methods and improvements in old ones.

From time to time, radical relief is sought from localized pressure. A committee of the faculty may be appointed to study the entire curriculum, and to make recommendations that may alleviate the situation. The gist of the committee's report is apt to be that no relief can be found, except by a general "cutting out of details." This, indeed, may sometimes be necessary; for there is always danger of giving undue prominence to descriptions of methods and appliances, the details of which vary as practice changes. But, if the pruning knife be too liberally or unwisely used, in the case of a subject already being presented in a highly condensed manner, the impression on the student's mind is weakened; for details that show the application of theory are aids to mental digestion.

What is the remedy for this pressure for time? To be entirely frank, I think there is no positive remedy that would be generally acceptable. In most cases, the teacher must make the best of a congested condition, brought about by the multifariousness of our present-day engineering. But, this is not to say that the situation is hopeless, that it may not be ameliorated.

II.

The attitude of many employers of young engineers is in some respects like that of purchasers and users of manufactured commodities. They have their ideas as to what the quality of the graduates of the mining schools should be; and, as they are by no means inarticulate, their opinions and criticisms often go direct to the teachers in the schools.

While expression of the employer's viewpoint is always useful, it is of most value when it comes from the manager or superintendent who himself has had the advantages of a technical education. He is then familiar with the schedule of study, and knows from personal experience how hard it is to find time in the brief undergraduate period for an adequate training in the essential preparatory sciences, as well as in the numerous highly specialized technical subjects that now so urgently demand attention. He will then have learned that, under our high-pressure modern conditions, the framing of a sound schedule of study consists largely in selecting what experience indicates as being of most value to young men beginning an engineering career, and that it is no longer possible fully to cover the field.

Some criticisms of the existing courses of study in schools of mines are based on the fact that the young graduate does not always make good in the first year or two of practical life. Inquiry into such cases generally reveals the real difficulty, viz.,

that the beginner has failed to meet the requirements of the particular position in which he finds himself immediately after leaving the school, because he lacks some special knowledge or aptitude. That such failures occur cannot de denied. The questions then arise: (1) to what extent do these failures constitute a valid ground of complaint against the system of training in the schools? (2) is it possible to give students a sufficient variety of "practical" instruction to enable them, at once after graduation, to meet the employers' demands, in whatever lines of duty they may be called upon to serve?

Leaving out of account the question of the student's personal equation, and recognizing that not all young graduates are fitted by nature for the successful practice of engineering, it is necessary to keep in mind the true aim of a well organized school of mines. It is certainly not to prepare its graduates to perform some specific round of duties, which may form but a very small part of the wide field of mining practice. No course of training could turn out young men, every one of whom would be competent to deal instantly with any and all of the problems that may have to be met by an engineer. Undoubtedly mining students could be prepared for prompt, efficient service in some particular technical position; it is not possible to prepare them to fill immediately and equally well all of the beginners' positions usually open to young graduates. The chief purpose of a technical education is to develop the reasoning powers and stimulate original effort, rather than to afford the student opportunity to collect a mass of engineering data.

In some schools much time is devoted to certain manual operations of mining. Laboratories have been established to teach students to run machine drills, make comparative tests of drilling speeds of different machines and shapes of bit, sharpen and temper drill bits, etc. One school has a laboratory consisting of a tunnel and power plant for carrying on actual drilling and blasting, studying the effects of different rounds of holes, and even for practice in tracklaying and timbering. Another has a "mine rescue" and "first-aid" laboratory. All these things are useful, and are good and proper if the school aims to turn out foremen and shift-bosses, or narrow specialists. But the time necessary to attain manual dexterity would better be devoted to the engineering subjects. How to run a drill can be quickly learned, if necessary, in the mine after graduation, but a sound grounding in mathematics and the natural sciences, and their engineering applications can never be secured so well as in the school class rooms and laboratories.

A wholly different criticism is that graduates of mining schools are rarely able to handle men successfully. It is often asked why instruction is not given in this important adjunct of all engineering practice. The obvious reply is that ability to

manage men cannot be acquired by any course of instruction and study. The subjects of sociology and economics may serve as aids, but experience is essential. This ability comes from a knowledge of human nature, which is generally gained slowly and often painfully—if it be gained at all—in the course of time, and by actual contact with men and working conditions.

Other specific shortcomings that may be objects of criticism might be cited. I knew a case where an excellent mechanical engineering department of a mining school was severely taken to task because one of its graduates, on beginning his field work, did not know how to designate the sizes of iron pipe fittings for making an inventory. It is probable, also, that, if he had been assigned to the staff of the master mechanic of the mine, he might have found himself unable, at first, to set the valves of a Corliss engine; but, if he had profited by the sound school training given him in the fundamentals of mechanical engineering, he doubtless quickly realized his ability to pick up the thousand and one practical details of his branch of the service far faster than could be done by his journeyman companions. Similar reflections might be made respecting the routine work of other operating departments of the mines.

III.

The conclusion would seem to be c l e a r. A thoroughly equipped school of mines is not engaged in training its students to be shift-bosses, or mechanics, or electricians. It must first of all see to it that its graduates shall have had a thorough drill in the basic subjects that form the backbone of the engineer's training. In framing a course of study that will accomplish this the teaching staff is forced to recognize the limitations imposed by existing conditions.

The great breadth of modern engineering practice, the multiplication of methods, appliances and types of machinery utilized in mines, constitute a mass of detail that can be dealt with only briefly in class room and laboratory. The mining course differs from the relatively homogeneous courses in civil, mechanical, electrical and chemical engineering, in containing a greater variety of subject matter. In each of the latter courses, the technical instruction is in more closely related subjects. Mining engineering, on the other hand, comprises applications of parts of all the other branches of engineering, besides the specifically mining and metallurgical subjects. This heterogeneous character of the mining curriculum is largely responsible for the difficulties under consideration. Thirty-five years ago the case was materially different. Electrical transmission of power was in its infancy, mechanical engineering was far less specialized, and the small variety of mining and ore dressing machinery made the equip-

ment and operation of mines a simpler matter. Hence, the attention of the student was concentrated in a narrower field.

No student of the present day, however able and industrious, can hope to acquire more than a general acquaintance with the great fields of engineering knowledge now applied to mining. He will have accomplished what is practically possible if, after he has completed his preparatory work in mathematics, chemistry, physics, mechanics, properties of materials, geology, mineralogy, etc., he succeeds in familiarizing himself with the salient features of those portions of tthe allied branches of engineering that furnish so large a part of the professional equipment of the mining engineer.

From the standpoint of the school the great cost of maintaining the group of engineering departments that contribute to the training of mining students is justified by the efficiency of instruction imparted by specialists in the several branches and the facilities they afford to earnest students in getting a start in their career. Students are not expected to become encyclopaedias, but they can learn how to search for and where to find the data for solving a given problem. This in itself is no small part of an engineering training. They also learn something of which every teacher in a technical school is thoroughly convinced, namely, that no engineering subject can be completely covered by the class room and laboratory work assigned to it. Even with the aid of conscientious collateral reading, the student can succeed in making only a general survey of each subject. He cannot expect to master any part of it, except by neglecting other parts; but he may hope to attain some familiarity with what may be called the literature of engineering, and a conception of the great fields of engineering knowledge, the extent of which is only faintly realized by those not fortunate enough to have undergone a school training.

To aid the student, numerous pocketbooks and handbooks have been published in recent years, forming a highly condensed library of engineering practice. Their possession, together with a general knowledge of their contents, constitute no small part of the engineer's stock in trade. But they are only the tools of the engineer, the intelligent use of which depends largely upon the school training.

In the usual four-year course the fundamental sciences can not be efficiently dealt with in less than say $2\frac{1}{2}$ years, leaving $1\frac{1}{2}$ years (with the vacations) for the technical subjects. It may not be amiss to state that, in mining schools, the word "vacation" does not possess its usual meaning. Out of the $3\frac{1}{2}$ months' vacation each year, from 2 to $2\frac{1}{2}$ months are occupied by required field work in surveying, study in mines and ore-dressing plants and field geology.

Realizing that even the ablest student can do no more, after he has been trained in the basic subjects, than to touch the high points of the great range of modern engineering practice, it must be recognized that: (1) No mining school can fit its graduates to perform immediately and successfully the routine duties of all the positions in which they may happen to begin their field careers; (2) Even if the pruning-knife be freely used in cutting out instruction in technical details, a four-year course no longer suffices for an efficient training in mine engineering.

IV.

In recent years the conviction has been gaining ground amongst teachers in mining schools that, notwithstanding the difficulty of finding time for the numerous technical studies demanding attention, the course should include certain cultural, humanistic subjects; that there is need to widen the student's vision and counteract his tendency to unsymmetrical mental development. Amongst such studies are: English Language and Literature, History and Economics. Here at once is a serious addition to the curriculum and the list is easily lengthened. If important studies are added to the four-year course it would seem necessary to curtail some of the engineering subjects, or omit them altogether, unless the period of training be extended.

Several schools have attempted to solve the problem by prefixing a "preparatory" year; others, by adding a sort of post-graduate year. One school has recently adopted a six-year schedule. Its group of engineering schools, including the school of mines, has been placed upon a graduate basis, the length of the mining course being reduced to three years. Candidates for admission to this shortened course must have had such preliminary general education as can ordinarily be obtained by at least three years' work in a college or scientific school of high rank. The immediate effect of this change is that most of the subjects formerly given in the first year of the four-year course are now included in the entrance requirements of the school of mines.

Time is thus afforded for some of the cultural studies. One of the outstanding purposes is to insure a better training in the use of English, so important to an engineer in his professional intercourse with colleagues and clients. The man who can express his opinions and write reports in lucid language has a great advantage over one who, though perhaps an equally able engineer, habitually speaks and writes in a slovenly, uncultivated manner. The other added studies contribute to a liberal education, that may be expected to prepare graduates for professional practice on a higher plane than is ordinarily attained by those who have devoted four years exclusively to scientific and technical studies.

Whether this expectation will be fully realized it is not possible to say until the new plan has been longer in operation. It may be objected that comparatively few young men can afford the time and money for so extended a course of study. While such a training has very much to recommend it to those who desire a fuller, more completely rounded education, its ultimate success must depend upon the support of the public having sons to be prepared for the mining engineering profession.

V.

Granting, as I think has been shown, that a four-year course in mining is too short, is the plan mentioned above the best that can be devised, or can the objects sought be attained in some better way? Some teachers of mining engineering may question the wisdom of separating the course of instruction into two distinct parts, believing that all of it should be under the jurisdiction of the engineering faculty.

A fairly satisfactory solution of this difficult problem might be found for most mining schools by lengthening the period to five years. This would relieve the pressure now so severely felt, while still furnishing opportunity to add to the scientific and engineering studies several of the desirable cultural subjects. But, I believe such a suggestion should carry with it the proviso that the entire course be placed directly under the engineering faculty. This plan has two specific advantages:

(1) It would tend towards better co-ordination of instruction by insuring undivided responsibility in planning the curriculum and administering the school work. In a course divided between college and technical school not only may there be "lost motion," but the members of a college faculty, even with the best intentions, do not always have full sympathy with the aims of engineering students, nor, perhaps, a sufficiently clear perception of their needs.

(2) It would facilitate changes and readjustments of curriculum, as made necessary from time to time by the development of educational and engineering methods.

Some have thought that the best results would be obtained if the added subjects were taught by members of the engineering faculty, purely from the engineer's standpoint. For example, that the English should not be a broad course in English Language and Literature, but should consist of special instruction in "technical" English. I would not advocate this any more than I would advocate having the civil and mechanical engineering subjects that form part of the mining schedule of study, taught by members of the mining faculty. The staff of the school of mines should be responsible for deciding upon the particular cultural subjects to be added, and designating their general scope; but the instruction should be given by specialists in each branch.

As to the substantial benefits that may reasonably be anticipated from a lengthened course there can be no doubt. A better education will be secured than that which results from confining the student's attention too exclusively to the material, technical branches of human knowledge. "Education" connotes something quite different from "training," as ordinarily applied to the preparation for an engineering career. The longer course will afford more opportunity for cultivating the mind and forming habits of observation and sound thinking; all leading to the mental power that renders the truly educated man more widely adaptable and better able to solve whatever problems may be presented to him.

It has not been customary in the past to class mining engineering amongst the learned professions, as of law and medicine. Why should it be permitted to rest under this implied stigma? Together with other branches of engineering, it is in reality a profession, in so far as its practitioners measure up to true professional standards. It deals with one of the great basic industries, supplying a large proportion of the things we use and must have in our daily life. The degree of the development of this industry may almost be considered as an index of civilization. The calling of the mining engineer is a high one and his education should be on a correspondingly high plane of endeavor and accomplishment.

TRAINING IN COLLEGE FOR THE PRACTICE OF METALLURGY.

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The earnest desire that we feel to bring technical education to the highest efficiency and service expresses an attitude natural to engineers. In this desire is included that of improving the training in metallurgy, which is an important branch of engineering practice. The possibilities of improvement at first seem many, and advancement seems simple; but conditions under which an educational interest can permanently yield returns are not simple. They are precarious, and extremely complex. All classes of society have interests in education. Their interests are separate and different. Changes that we, ourselves, would propose as desirable, must pass in judgment before a world of people and encounter opinion from many quarters, and meet experience entirely different from our own. College instruction is dependent upon public opinion for support and for success. We look for a base line that is correct and stable, and should expect it of higher institutions of learning, with roots at the depths of all the world holds permanent and desirable; but we find the stability only that of a deeper public opinion. We know that great principles do not change, but we recognize that great working practices must do so. Change is necessary for adaptation of the old to the better and the new, yet no single interest has the mastery of the direction.

The cycles of change in educational purpose are of long measure, bearing upon all people, extensive practices, and set customs. The consequences of the change are far-reaching, difficult to detect, and more difficult to appraise. In looking back through the years to efforts that have been made in the different colleges to improve training it is apparent that the institutions are in close touch with the changing needs and possibilities that the world presents. We would not be rated among those who are unmindful of the difference between change and progress. The difference is one that many people who exert an influence upon public opinion are prone to ignore. People sometimes greet change as a sign of life in large affairs, failing to observe that the disturbance, which loosens the set conditions and provides for progress, reacts in two directions and destroys existing good that we had not seen. We do not look to change as an assurance of progress. We would think of it in terms of rate rather than of direction, and would hope for progress through reason.

There are many different opinions on the training that best prepares a man to become a metallurgist or a metallurgical engineer. There is question as to how much of this training should be in the school and how much in actual experience. A few people believe that college training contributes little. Others consider it helpful, but not imperative. Many hold it essential on the grounds that life's calling is enlarged by it and that human welfare is safeguarded by it. Those who believe in college education are not convinced of the kind that is best. Different colleges have acted differently, both as to the duration of the course and the methods of instruction. Many men, who are distant from college interests, have views which they have not weighed. Others, to whom we would turn for the broadest judgment, we find often narrowed by temporary conditions arising at the instance of the call. Most of us are skeptical about anything that is believed to replace experience, especially such experience as we, ourselves, have had. Most of us, however, condemn our own experience in part, recognizing in it blind gropings to secure ends that now are seen to be easy of attainment, or in better judgment, undesired.

The productive industry embodies an opinion on engineering education. It demands young men trained for useful service. Often the first service is of a highly special nature. Sometimes the college graduate is expected to come prepared to meet the special details of a specialized branch of a specialized profession. Sometimes he is assigned to duties beside trained employes regularly accustomed to the work in hand. His capabilities often are judged by his first performance under severe comparison. Under men who have received college training, or who know its limitations and its powers, he generally is directed in the presumption that there are latent, within him, capabilities beyond the immediate task. Employers, as a whole, take college men in the knowledge that much experience remains to be acquired; yet deferred capabilities command little regard when there is urgent work in hand. The impression that is made by the man's first experience depends upon the personality and training of all concerned, but the opinions that are formed are frequently sweeping. The more advanced service of the college man, which comes at a later time, we do not so often hear reported. Always it is highly important. Almost always it is successful. The success is attributed, generally, to the intellect of the man rather than to the institution that has trained him. Faulty practice in the higher service of engineers exists too. Often it escapes attention or report for the want of a higher judge. The opinion regarding it gathers in devious ways but the pronouncement upon success is commonly a popular judgment, built upon a commercial basis. We may not notice when it exists, the waste, the loss, the mismanagement, the inefficiency, in result of improper or inadequate

training, so long as the rate of activity is high and the balance is on the credit side. The opinion of engineering practice upon educational requirement is not co-ordinated. We are at a stage in progress where there are many opinions. We should have understanding to justify them.

The question arises as to whether there is, after all, a basis upon which the experience of different men can be grounded for a common judgment. Opinions are the essential motives for individual action; but in collective dealing the same opinions, if not formulated for analysis and comparison with those of others, are unsafe indicators of progress, and may be incumbrances. Opinion as a basis for authority has always been distasteful in principle to our American people. It is a part of the main idea of authority, with power, that has brought us tyranny, calamity, and war. We can not pronounce upon the progress of college education without consideration and common conceptions. We must know how others feel and see the common purposes recognized in education. We can judge best the requirements of technical education when we have considered the underlying relations.

The colleges of university grade, in which degrees are given at the completion of a formulated course, based upon training in Metallurgy, have become an integral part of our educational system. The institutions are maintained in part by the state or public and in part by private endowment. All attract public interest and rely upon continuance through public good will. Tuition, which is charged in some cases, partly defrays the cost of instruction, but the income from this source is relatively small. Some of the schools are independent, not being involved in activities outside those looking to the practice of Mining or Metallurgy. Others are subordinate departments in greater universities through which they derive support and with which they co-operate in the presentation of courses and the interchange of instruction.

The service of all these schools or colleges is closely related to productive industry and economic welfare. The supply of trained men in metallurgical science has been of incalculable value to the country in time of war. In times of peace they have been always an active, dependable resource. The material achievement of the world has come about through the service of men such as the engineering and technical schools provide. Colleges that supply them are upheld by all who have the vision of a civilized world. The public expectation, therefore, has an important place in the motive that defines them.

Since technical colleges must function in an organized and complex educational system not only must industrial need and public expectation find harmony of purpose, but numerous other requirements must be met. The conditions of organization of the institutions now existing show something of the avowed pur-

poses, and the field is further open should new institutions be required. We observe, primarily, the limited extent to which the service of colleges is restricted by the men or interests that have founded them. They are, without exception, dedicated to public welfare. We would know something of the direct beneficiary intended for the service. We would know whether it is to be the student who attends, the parent who sends him, the community of which he is an exponent, the employer who will find use for him, the industry that will require him, the nation that will be influenced by him, or humanity that will grow as he may grow. We would see whether this service is intended to be direct to the people, through opportunity offered to all in education, or into defined channels, such as prosperous industry, bringing benefit to all, national economy, lightening the burdens of all, or character in human relations, providing safety to all. Our colleges are uniform in the high order of service to which they aspire, and the high purpose is corroborated by every contact with the public.

We do not find in these institutions the self-contained features of private enterprise. Activities and benefits are directed outward. We do not expect, accordingly, service restricted to any class. The service is impersonal. We do not find them organized to serve the private ends of individual benefactors. Benefactions, so restricted, would be poor investments, and would be unwelcomed. Colleges do not serve the student to a career solely that he may gain advantage over other men. The graduate knows that he is the bearer of a trust, the representative of an institution, the sharer in a purpose, and that the purpose is high and is consecrated through his college to his nation and his human kind. Colleges do not contribute to industry for the private benefit of one interest over another. The single interest of industry is competitive and needs service above the line of competition. We do not expect the institution of learning to restrict the benefit to any privileged race, in times made possible by peace or its assurance. Science and understanding are drawn from all lands and rebound upon the giver in the measure by which they go forth.

The technical college does not cast its activities directly into an abstract world of society. There are constituted channels and agencies through which it is organized to act. Such agencies are: the industry which it seeks to advance, the young men whom it seeks to train, the world's store of published, available knowledge towards which it purposes to contribute. Humanity extends before these agencies in need of understanding and guidance and its appeal is for openness and integrity. The good that emanates from the college is carried out by those who have received, and who, through habit and insight, are the motive-force in the world's material interests. They are the only directors of prog-

ress that are hoped for, and are the needed exemplars of business transaction of the future.

There are, then, numerous divisions of society that feel a special or exclusive responsibility over the work that is done in colleges. They are not all looking to immediate convenience. Most are in search of a higher public welfare. We all would shape our personal needs that they might conform, so far as the highest may be known. The immediate need in Metallurgy is efficiency, economy, capacity, and development. The ultimate need, however, is understanding, released from restriction and encompassing all purposes inclusive of those which are broadly humane. Two separate interests then arise in the college purpose. The one is a narrower one, tangible, practical, commercial and self-seeking. The other is the broader one, moral, general, ethical and humanitarian. The serving of the applied, commercial purpose is of the narrower interest, concrete, measurable, and for the individual practical. The serving of the broader purpose is abstract, hypothetical and seemingly less urgent. The commercial purpose is possessed of the spontaneous force of direct profit under the stimulus of the commercial and competitive system in which we live. The broader purpose lacks the visible incentive of so concise a gain. It requires the service of the college. The understanding of human as well as physical principles and the knowledge of fundamental laws form an impersonal structure that carries the elements of greatest service to humanity. These elements must be found present in the scheme of education to justify the existence of the college.

The training for the practice of Metallurgy includes items both of the immediately practical and those of the less tangible but broader motive. Subjects may be grouped progressively, whereby at one extreme is the idea of immediate, technical utility, preparing men for lives of industrial usefulness, while at the other is the idea of highest purpose, looking to the ultimate betterment of society. All are necessary to a modern education in engineering. The order of content does not imply, in the separate concepts, either the idea of relative desirability or priority. It is the blending of these into the engineering profession by which the relative superiority appears in the application. They may be thought of as qualities in the training but they take the form of purposes. The first or narrow purpose, at the beginning of the series, consists in the training of young men for immediate service in specific commercial or industrial activities. There then follows the second, as of a higher order, which consists in the training of the understanding in the principles that underlie the practice. Here is included the practice and technique necessary for illustration, the knowledge of the sources of further information and an element of research. The third purpose is that of training to secure such

interest and insight into the possibilities of science and economy as to give power to develop, investigate, originate, discover and invent. Here is required the broadest training in principles extended into the more limited but chosen application, calling into service the widest range of judgment, consideration and study that is compatible with well balanced training. Beyond this lies a fourth division, the psychologic, economic and social aspect of engineering, which is the basis for broad application, safe guidance and higher direction. The fifth, extending beyond, to the border of abstraction, is ethical and aesthetical refinement, appearing in sympathies, in taste, exemplified in art, culture and moral purpose. It may be construed as a development of the self in the capacity that lies above and beyond the reasoning power. Here is contained the development and broadening of human sympathies and human understanding. The training in college is concerned chiefly in those powers of the mind and body that can be altered or directed during the term of study, as distinct from those that cover equally the entire period of life. The training thus should be less forcibly directed upon those healthful and necessary life activities that begin in early youth and endure through life, and in college require a merely normal but wise maintenance under guidance. All the subjects before enumerated require definite representation in instruction. In all there is requisite the maintenance of the interest, the guidance to sources of further knowledge and stimulation for progress, continuance and application.

Training for immediate service, in the specific branches of practice, is the part of engineering instruction that is outwardly most evident. It is the criterion by which the curriculum, sometimes, is adjudged practical. It attracts by its appearance of utility and commercial value. We do not have to go far into this type of college training before we discover that we can not attain the fullness of understanding that seems to be required in the specialized practice without encroaching upon time needed for general understanding and acquaintance with other specialties. This leads to an endeavor to secure both the specialization and the breadth of training, but it results in a compromise to both. Specialization obstructs the purpose of education when carried to the point of omitting the subjects that a normal man should know, and ignoring the qualities that we recognize as expressive of enlightenment, culture and education.

Most of the special branches are intricate. They seem all important to the specialist, engaged in the particular calling, but we find that the proficiency that is desirable requires the study and practice of half a lifetime. The college man that has been trained only in a specialty, which he will have to follow when his school days are ended, finds himself an uneducated man, fitted to

do only the few things that would have been learned as a matter of course in his early practice. Training of this kind is of the greatest immediate convenience to industry; but the convenience in the end amounts only to relieving industry of the cost of training its men. Such training, for peculiar service, otherwise would become an added item of operating costs. When borne by industry in open competition this cost subjects no industry to advantage or disadvantage beyond that of another. The effect of doing this work of industrial training for industry as a whole, is not strengthening, except so far as substantial college education enters the training as an unsolicited premium. Sometimes the capacity for the immediate work is preferred unspoiled by the broader outlook and by capacity for advancement and higher service at a later time. It is the kind of training which industry, for its permanent good, should not grow to believe to be its proprietary right. It is the education of the trade school. It is a feature of education in colleges where the practical elements are set forth as of prime importance. The wise and moderate allotment of time to it, in college courses, requires strength of college purpose.

The second or higher aim in technical education of importance to industry and to the people is that of encompassing, in some manner, the understanding required for the immediate task and, at the same time, of providing for the next step and later steps in progress. Training for immediate usefulness in specialized service takes a subordinate place to this, though the demand for it be insistent. Despoiled of its applied character college training, however, would lose its interest and its life. The graduate, unprepared to meet the reasonable demands of early practice, would be found weakened and unsuccessful. Unqualified to gain a foothold in productive industry he would be turned aside, at a loss to himself and to the public. There is, however, need that people know that technical education consists in something other than the mere habits of hand and familiarity with industrial practices of today. The care is to avoid excess, and to moderate the popular tendency to introduce a preponderance of the so-called practical courses into public training and education. Mechanical attainments the man must have. Metallurgists, moreover, must have the skill to survey, assay, draw and compute, but these acts do not constitute metallurgy. There is needed, also, at an early time, a knowledge of men and the recognition of efficient operation. Much of the practical knowledge that we regard essential and would put into our college courses, is an inborn gift of man. A part comes from early influence and environment. A part grows continuously during the college life through friendships, discussion, acquaintances and interests, independently of the tasks assigned. Some of it is natural to maturity. All of it is acquired with wonderful celerity by college men who have been trained in fundamentals.

The requirements of handling labor, its discipline and the significance of costs, college men are keen to observe when the economic need arises. The capacity for directing service is in part specific for the locality, demanding habits, principles and understanding which no man, as yet, has mastered in the entirety. Whatever nature the case assumes, college men are quick to understand, eager to manage with success and are uncommonly tactful, intelligent and efficient. Training at the works, at the mine, the mill or smelter, in an operating laboratory, or in the larger field, all give vigor to the understanding, but the growth in capacity and ability is proportionate to the fundamental training in principles that has preceded.

Without the development of the idea before the handling of material begins, time is lost, dangers are encountered and mistakes are made. The mind, unprepared for the confusion, can but learn to be unconcerned by most of it. The training that is required cannot be handled during the experience. Impressions gained while taking a part in commercial operation are vivid, and are evermore useful as a basis for illustration, but they are limited, meagre, and the order is unsuited to the developing scheme of understanding. Such impressions, skill, and visual remembrances, require to be established and drawn upon as needed, but work assigned for producing and multiplying experiences must be limited to small units in duration, and recommended with the knowledge of the cost in time and educational energy. The valuable service to be had by the use of laboratories, sometimes extensively equipped and costly, is apparent in this connection. The study of the subject is most effective where and when the items of experience are controlled and are not pressing in overwhelming numbers and where the mind has time and freedom to develop not reflex but the idea.

The training of higher order thus deals with the understanding and the principles that underlie practice. The work of instruction is descriptive, in a measure, as illustration becomes required. Examples are taken from all sources and used by all means to fit the end, but the arrangement and the progress of the work is ordered to the progress of the growing understanding. So far as instruction is informational the capacity for retention is limited. So far as instruction is fully accompanied with experimentation or material representation, the progress is slow. The training in principles, on the other hand, which holds the practical exercises in limitation as the means and not the end, is constructive, and encounters no limit to the rate, the application, or the growth. It incorporates into the study the views of all work, at all places, and all times, and builds a foundation upon which any detail of practice may be placed, examined, reasoned and mastered. It contains the sources of further information, the means of further

development, and indicates the imperfections and the merits of present practice. It constitutes the freedom of the mind to move from one act to another, and it provides the resource necessary for the execution of any charge.

The essential characteristic of education is that it rearranges the order of the items and forms an intelligible system removed from the chance occurrence of the actual work. The development of the idea is the elementary act of developing understanding. The idea may seem to spring from obscurity, but whether we know or not, it follows other ideas and is ranged with others in an endless chain. When the principles have become mastered, practice and experience become a continuous exemplification of the products of thought; and whatever the practice is, or wherever it may be, it evermore is rich in interest, in significance and importance. Metallurgy, taught to students in college, draws upon experiences and illustrations, but they must be drawn upon demand and in the measure needed.

The training in principles, with all facilities that may be required, is the part of life's work that can be done in college. It can be done nowhere else so well. It is the indispensable training that a successful man must have. It may be in part given by assigned and carefully selected reading. It is aided by discussion and class-room study. It may be brought before large classes in the form of lectures. It may be supplemented and fixed by home study and reports. It may be intensified and measured by examinations. It may be incorporated into brief exercises of quest looking to the sources of information in libraries, looking to the revelation of advised experiments, and looking to the practices at operating establishments. For the training of the metallurgist, the subject-matter must cover the entire extent of Metallurgy.

The field of Metallurgy is a large one, and the profession is one in which the unity is not closely maintained. Custom, development and practice have drifted and expanded until now the calling is not represented by the earlier definitions. The demands upon the Metallurgist, within his field, are extended and interchangeable, recurring from all parts of the practice and requiring all possible detailed knowledge as well as a general understanding. Specialization within the field of Metallurgy, at the beginning of the career, aside from the educational inadvisability, is limited, and fails to become effective on account of the irregular call for men in the separate branches, and the needed substitution of the differently trained men that are available to undertake the work. Specialization in the higher practice of Metallurgy results from the changing call of practice for the adaptation of men to the requirements of new circumstance and environment that arise in every man's progress. Practices which seem permanent while

existing are seen to supersede one another in rapid succession when viewed through a term of years. Though specialization may be favored by the immediate convenience of a special industry, and by a seemingly remunerative inducement, it is unsafe for the man in college looking forward upon an entire lifetime, and unsound for the world looking for men who later are to be its guides in the full understanding of affairs.

In attempting to define the field of Metallurgy we find the calling a composite one, including many dissimilar interests. As is the case with the other sciences, all of which claim exactness as their supreme quality, it is indefinite in its boundary, and is composed of elements that it holds in common with many of them. The science acquires unity in the fundamentally scientific features and in certain economic and practical ones. The coherence, so far as economic, is through the treatment of the products of mines. The scientific unity is in fundamental principles which are drawn chiefly from chemistry, physics and other exact sciences. The coherence in practice lies in the design, development, construction and operation of plants, appliances, practices or processes, in part or as a whole, for the treatment of ores or the refining and manufacture of metals, by the application of scientific and ecoomic laws. Certain mines yield gold, and others iron. The superficial relation between the smelting of iron and the extraction of gold is remote. The unity, however, develops when the scientific understanding of metals, ores and minerals appears. There are properties, which all metals have, that require comparative study. There are relations in the processes of sublimation and distillation that are the same whether the metals be zinc, mercury or arsenic. There are laws of solution, of mechanical separation, of fusion, of smelting, that are developed for the practice of one metal in the study of another. Economy in handling and utility in construction enter all the branches of the subject, being co-ordinated by the larger application. Into the science is gathered much having bearing upon the purity of metals, the examination, analysis, assay and minute examination of them, and of the ores which contain them; the fashioning, shaping, rolling and treatment of metals, and the influence of impurities and chemical composition upon the desired and undesired properties; the economic conditions that govern the possible production of metals, bearing upon the processes, chemical, physical and mechanical, that represent the manufacture; the means of operation and measurement at high temperature, the conditions at ordinary temperature, the appliances and devices for lixiviating, elutriating, and concentrating of mineral products, and the smelting of ores. Furnaces, retorts, mechanical devices, tanks, vats, screens, crushers, conveyors, all come into prominence in the practice of Metallurgy. Much is taken into the subject in the nature of the knowledge of fuels,

which figure prominently as one of the raw materials, and which also require washing or concentration by processes identical with those required for metal-bearing minerals. Refractories are so indispensable in the practice of some of the operations of Metallurgy that the knowledge of these is of equal importance to that of the metals, while the treatment of mineral products to recover or manufacture refractory agents becomes a part of the economic practice that the Metallurgist must understand. Mineralogy, Geology and Mining are closely associated with Metallurgy, in the practice, and a familiarity with these, and an understanding of the principles and practices that they involve is necessary in the practice of Metallurgy. The common ground that comprises the items that enter the practice of Metallurgy is shown by the drift of general understanding regarding it. The foundation of Metallurgy and of most of the interests that enter it is placed substantially in mathematics, chemistry and physics. The unity, which is lost in the diverse applications, is found in the required understanding of common principles.

Training in principles, which clearly is the basis for a successful practice, we find to be peculiarly associated with the power necessary for development, improvement, investigation and research. Research has been always one of the recognized aims and motives of education. The institutions of learning have come to be the dependable exponents of the world's published research. In Metallurgy, as in other applied sciences, we find that research is a quest, having in view an application. Since application in general practice depends upon economic success, it is a quest that presents a commercial aspect. It contains elements that must run either parallel with prevailing commercial interests or counter to them. It stands always in the precarious position of being either assimilated by industry or annihilated by it. Commercial research, conducted for the public good, in college or elsewhere, requires a clear outlook, a steady purpose, and a high aim, to convey the service to the end desired.

Metallurgical research in college takes three important forms by which the purpose is directed either (1) towards the training of men for their power in the propagation of research, or (2) the accomplishment of discovery for the betterment of the industry as a whole, or (3) investigation within the field of Metallurgy for direct assistance to specific interests, which presumably should be shown to be also public interests. In the treatment of this subject I am limiting the consideration to the training of men for the practice of Metallurgy, and am considering only the first one of the three forms of metallurgical research in college that are named. As a feature of college training, research is naturally expected to play an important part.

There is probably no word used in science that calls to different minds a more varied range of images than does the word

research. To untrained men following Metallurgy, it means ore-testing, to others it means the development of a business system, to others it means a pleasurable compounding of material substances. To an omniscient Creator it must seem like an unenlightened juggling of heavy materials to find out facts that should have been known before, through reason. It is one thing in one calling and another elsewhere. In some lines of endeavor it requires the closest scrutiny, the minutest observation and the extreme of patience. In others it demands the sweep of vision and the immediate elimination of obstacles. It may be summoned by an urgent purpose, or measured lingeringly, in the love of discovery. It may be in the expectation of remuneration, or renown, or in the ambition to render service to the world for the world's sake. There may be suggestions for it, requests for it, demands for it, or it may emanate from inspiration. It may take the form of a contribution of routine service, or the command and direction of the work of others. The hope may be for a law, a process, a system, or a chemical substance. It may consist in the rearrangement of knowledge that someone else has obtained, or the wandering search for new items to add to those we have. We can not lightly define research, nor formulate the qualities that are required for its prosecution. The purpose needs be generous and noble. The execution must be wise. The promptings are seemingly the love of truth and the desire for understanding. The manner is constancy and persistency. The means are strength, intellect and material equipment. We do not hope to discover all the elements of discovery.

Clearly, research can not go on at the rate the world requires without support; and as surely it should not go on at public cost without publicity. We must approve of the instinct that seeks addition of facts to the fund of total knowledge, taking the items from the great unknown, inaccessible, or remote, and placing them at the service of any who seek knowledge. Research is closely associated with education. It is the natural outgrowth of education. Except as an incident in education it can not be taught. We can teach methods, impart traits, expound truths, or guide instincts, but we can not teach research otherwise than through the natural course of education, nor can we educate without employing the elements and the methods of research. The one is the natural reaction of the other.

It appears unwise, in undergraduate college work, to distort greatly the trend of development in the mind, to introduce a prolonged effort in research. It leads astray from the immediate concern, takes a required, independent direction tangential to the educational purpose, and fixes the pace to the staggering of a ponderous guide. The idea of research enters into each day's accomplishment in education, and is an element in all proper study.

We would not insist on the formal undergraduate thesis. It commonly has not a high research value, and is of varied and questionable educational value. There is also a limitation to the value, in some cases, to the student in Metallurgy, even of the graduate thesis. As a generous contribution to knowledge, when massive and long, it draws heavily upon the young man's resources at a critical time in life when the activities should be directed towards the work to come. The acquirement of experience and the practice of the profession properly are in order when the mind has become matured sufficiently to justify the consideration of real research in this engineering branch of science which is characterized by its application. The instinct for research and the desire for its publicity will reappear later in the life of a well trained man. In engineering, it is the progressive and enlightened practice, with the open and co-operative instinct that constitutes the highest service in research. Research is promoted by the education that develops both the ability and the public spirit in men.

The psychologic, economic and social aspect of engineering practice arises as a necessary requirement in the preparation for a career in Metallurgy. Alone, neither psychology, economics nor sociology can be regarded superior to the applied science of Metallurgy, either in disciplinary value or human utility. Like foreign commodities they acquire, in Metallurgy, an enhanced utility by their new environment. They humanize the material science of Metallurgy, and extend and facilitate its application in a world that is dominated by human interests. The student of Metallurgy has no abundance of time to devote to intricate, descriptive matter of a remote kind. Organized into a system, treated as a science, and limited to the recognized and accepted laws, facts, and principles, these sciences carry a power into technical practice that is greatly to be desired, and find a place of application not exceeded in importance by that of any other. They may enrich the world through the scientific mind and the honest purpose of the metallurgist by all they have to give.

Training pursuant to culture, refinement, taste and the moral sensibilities are not equally thought to be essential in the preparation of the engineer. The severe conditions and hardships that are encountered in the earlier years of practice, for many of our engineers, permit of no weakening of the body, nor of the mind, by sensibilities not required. The service demands accomplishment, subduing obstacles of whatever nature. The work requires unremitting advancement through mathematical precision, strength in planning, constructing, executing and operating, in the face, sometimes, of the severest discouragements of material, commercial and human origin. With these there must be constancy in routine, dependability and vigor in every charge. There is no substitute

for execution and accomplishment in the requirements under which the engineer is placed. We do not observe in any of this, the need of refinement, beyond that found in the instruments and agencies of his methods. We do not find moral initiative, beyond that required by expediency. The engineer that answers only to this type of executive agent is not a man. He is a powerful and highly effective machine. He can be used for constructive or destructive work. He is powerful for a good purpose or an evil one. He is a dependable agency driven by the power of money. It may be thought by some people that schools of engineering and applied science should be operated to produce agencies of this sort, as men of this type. It may be thought that we are privileged to shift the responsibility of the directing force possibly to the requirements of capital investment. But humanity has said no. The world does not want men who hold the keys to its storehouse to be agencies at a price. There is a refinement in practice in which the engineer has a share in the higher command, and must bear a share of the moral responsibility. His calling brings him into contact with directing forces clad in sensibilities and highest sympathies. The refinement to understand, the vigor to execute and the morality to safely direct, comprise a part of the equipment in which humanity demands he be vested. All recognize, in the extreme, the uncouth, uncultured, unlettered man, unlearned, unwashed, unmoved by higher motives except those most primitive and concrete. He is of a common type. If there is any degree in which these qualities can be permitted in our engineers it is a greatly moderated one. The hard life, which is made the harder by human sensibility and moral fiber, is made the richer by them. Severities never bring enduring degradation when the better foundation has been laid. Engineering practice has come to demand moral initiative, culture, and familiarity with recognized social amenities, in the men who are to be looked to for the responsibility in the world's progress. The finer quality is found in our successful men in the places of high responsibility. If not obtained early in life it has to be acquired at a later time, at great cost to the men who receive it and to the world upon which they have operated. There is demand, it is true, in industry, for men trained in applied science without regard to human, social or moral refinement. Colleges that supply them are dealing in affairs beneath their grade, and are betraying a trust that is placed in them by humanity. The tangible elements of this training take many forms. We recognize and know them, but we must provide a time and place for their acquirement, by the life, influences and courses of instruction at college, by daily gain throughout the entire period of the college course.

The qualities of engineering training, which extend from the material and applied to the human and ethical, by gradations, which

have been considered, can not permit of long intervals during the college period when any one has been left unadvanced. The emphasis is upon training in principles. The work is amplified by short, definite, effective experiences, in application or illustration. It is extended to provide the exercise of the trained mind in the creative activities of research. It is humanized by psychologic, economic and sociologic teaching in a larger aspect. It is tempered by the influence of culture taught in the humanities and imparted by correct environment. It is guided with a moral outlook into life. It is supplemented by such exercises, instructions and activities, directed towards the maintenance and improvement of physical health as the college residence may require. Trained in these fundamentals, a man's intellect is receptive to the highest purposes we know. Trained in science, prepared in engineering, and directed by the agency of good will to human welfare, the engineer's life is one of most needed service.

We do not attain the ends of education by merely recognizing the aims. The recognition, however, is the first requirement in making attainment possible. Improvement will not happen, as a result of change. It requires the studied effort of us all. We do not find radical changes that seem to be required, but we see directions that appear desirable, and others not. Particularly we find extremes that seem to typify the immoderate and bad, that indicate to us the wisdom in many practices we have today, which are the outcome of years of world experience in the development of education. Many practical conditions retard and interfere in securing results that appear on the whole to be best for all. Colleges must see that the responding to a demand for partly educated men, specialized for technical service, floods the profession with men of a kind not suited to the world's greater need. Colleges that claim culture as a feature of the training must put the substance of solid understanding, in science and the features of engineering, into courses, to hold the standing exacted of their graduates in engineering service. The public must see the need of educating broadly for engineering service, must know the honor and the dignity of the profession, and substitute the higher ideal for a common one of education for a commercial trade. Employing interests must see the good there is to them, to all industry, and to the world, in encouraging a high purpose in college training, and must cooperate in employing the trained men of reputable colleges so far as the nature of the service permits. Public engineering sentiment must look with severe disfavor upon that operating practice, which is made possible by the chance or unequal distribution of nature's riches, where wasteful methods continue through half enlightenment or concealment under untrained men. Graduates must be reconciled to the routine of early service, and be prepared for the necessary limitations to advancement that are imposed by the

economic necessity. The nation must recognize the substantiality of men educated and adequately trained in applied and engineering science, for holding places of political responsibility and public trust. The betterment of education in Metallurgy shares attention with all technical and engineering education; and the uplifting force must come from all who have understanding and influence to utilize, uphold and advance the cause of substantial engineering education for the service of all.

REMARKS ON TECHNICAL EDUCATION.*

Albert Sauveur.

Harvard University.

This incident is only a passing illustration of what, to me, is becoming more and more evident as the years go by, namely, that it is not the knowledge acquired at the school or university which is later of vital importance to us, but rather the training of the mind which the acquirement of that knowledge implies. It is this training—this peculiar attitude of the mind—which distinguishes an educated from an uneducated man.

Have not most of us forgotten a large portion of the knowledge obtained at college 10 years after graduation? Do we cease, then, to be educated men? Are we less educated? Clearly not, for we retain, and possibly have developed further, that mental attitude—that way of looking at things—which distinguishes the educated man.

If this be so does it matter then what we do study while at the university or technical school? While I am not prepared to say that this is immaterial provided we study enough to train our mind, I do not believe that the selection of courses has the importance generally attached to it. I do believe that the educational value of a subject depends more upon its mind training power than upon the specific kind of knowledge which it aims to impart.

Hence the value of mathematics, even for those who never expect to be called upon to perform, after leaving college, more than the four elementary operations. It is, of course, evident that the natural bent of the mind should be followed in the selection of studies—that persons with decided scientific inclination should take up chiefly scientific studies, those with literary taste, classical subjects, etc.—but the value of greater specializing for the purpose of education is, to me, becoming daily more doubtful.

A scientific education should be obtained in four years, during which a sound knowledge of the pure sciences and the rudiments of the most important applied sciences should be acquired, thereby securing the desired mental attitude and scientific way of thinking. If the student then desires to take up as his life's work the application of science in some well-recognized field, such as one of the various engineering professions, his general scientific training should be followed by a course of two years of as practical a character as possible and devoted exclusively to applied science in his chosen field.

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*Reprinted with Professor Sauveur's permission from Met. and Chem. Eng., May, 1911.

During these two years specializing could hardly be carried too far. The student, for instance, should make up his mind not only to specialize in mining and metallurgy, but in mining *or* metallurgy, and in the latter case whether his special training will be in the metallurgy of iron and steel or of the non-ferrous metals. Should he select iron and steel, his two years of post-graduate work should be devoted exclusively to that one subject, or practically so.

In short, for the purpose of education and general fitness to take up a man's burden, let us provide a program of study as broad as possible, avoiding specialization, while for preparation in any one field of applied science let us frankly face the need of specializing; at this stage it could hardly be too excessive.

The prevailing practice is, of course, very different, the young man being made to specialize upon entering college, or possibly upon beginning his second year, and, therefore, at a period when very few can make an intelligent choice. Should he then decide to qualify himself for useful work in the manufacture of iron and steel he is required to follow for three or four years a number of prescribed studies of mining methods, ore dressing, the metallurgy of the nonferrous metals, while learning relatively very little of his chosen subject, iron and steel. His general scientific training is narrowed while the specialized knowledge acquired is not the kind he wanted.

He leaves college a less broad man than what he might have been with specific information in his chosen field too limited for immediate useful application. Nor can it be reasonably argued that six years is too long a period of time to devote to preparation for engineering work, for it would be an admission that professional work in applied science does not call for as broad and careful training as that now required by the best schools for the practice of law or medicine.

MINING AND METALLURGICAL EDUCATION.

F. A. Wildes.

Superintendent State Mines, Minnesota.

For the past twenty years the writer has had an opportunity to observe mining engineers in action, and practically no opportunity to study the work of metallurgists. During that time it has been his good fortune to come in contact with men from all the leading mining schools as well as some mining engineers who have fought their way up against great odds without the aid of a technical education. The field of observation has been limited largely to that of iron mining in Minnesota, where up to a few years ago it was popularly supposed that no technical mining skill was required. That notion is rapidly changing as mining becomes more complicated and beneficiation of low grade ores becomes more general.

For many years mining captains, superintendents and general managers were promoted from the ranks of the miner or from the clerical force, while the mining engineer remained a mining engineer. His work was to follow that of the mine foreman or captain. The tide is practically turned today. The mining engineer "lays out" the mine in detail before the ground is struck by a pick in the work of opening. Yet today many promotions are made from the non-technical branch of the organization. The reason for this appeared to lie among other things in the fact that many schools of mining did not lay sufficient stress upon the practical end of mine management, the handling of men, the cultivation of a good command of language, the ability to talk fluently while on one's feet, and to grasp matters as a whole, ignoring small non-essential details for the time being.

Men who have won their spurs in the battle of hard knocks and become the heads of mining operations, like to do business with a young man who takes things "hot off the bat" when called upon for his judgment in matters peculiarly within his field of action. He wants a general proposition, clean-cut and to the point. If at all interested he will then call for details. To be ready to do this the engineer must have given the subject previous attention and the best place to acquire this habit of logical thinking, etc., is at some good mining school. Habits on those lines formed there are likely to stay with him throughout his professional career. He must bear in mind that in order to advance he must at all times take a keen, active interest in his work and do just a little more than is required of him. Elbert Hubbard once said, "A man who does no more than he is paid to do, seldom is

paid for more than he does." In other words, to make himself valuable to his employer so that he may be promoted, he must be alive to the interest of such employer at all reasonable times. The question is how can these principles be inculcated so they may be a rule of action for the mining engineer? A good command of language necessitates much thought in the choice of words. The three "P's" of rhetoric, purity, propriety and precision, will come only from a clean-cut snappy course in school. It should not be considered as a mere nominal topic of study in the course but a full requirement.

The art of talking while on one's feet will necessitate the cultivation of careful, concise and logical habits of thought and general alertness of mind.

An engineer without the faculty of expressing himself clearly may have some of the greatest plans in mind and yet be compelled to play the role of the "Gem of purest ray serene" that we read of in Grey's Elegy. A short course in logic and argument would not go amiss.

The matter of mine management has not in the past received the attention it deserves heretofore in some technical schools. Until proven conclusively to the contrary, a school should regard a student as Napoleon is said to have regarded his soldiers, that every private carried a field marshal's baton in his knapsack. As soon as a student has shown himself lacking in the qualities of mind necessary in an engineer he should be dismissed from school. To be sure this should be the policy of all professional schools and perhaps is of most, yet many square pegs for round holes come from our professional schools to eke out a scanty living or to desert the profession at an early date.

A very commendable tendency in engineering colleges of late is to secure the services of practical men as instructors and to permit the instructors to engage in the practice of their professions as consulting engineers. This brings to the class room and to the student a touch of reality that can not come in any other way. Such practice will also encourage men of standing to give a portion of their time to teaching and thus bring to their classes a glimpse of the real world of action that the young men must soon enter.

Some one might suggest that this would make the course too heavy for the usual four years. This might be true but would it not be well to eliminate some of the highly technical features of some of the subjects for the sake of broadening the engineer to enable him to take a larger share in public questions, so vitally affecting all? The time has passed when a group of professional citizens might shut themselves up and take no part in public questions. He owes society a duty that no other technically trained man can perform. If he refuses to take his place in this contest, he can not be heard to complain.

The engineer can be a power for good in any movement as evidenced by the activities of several men prominently in the public eye at present. The fire that should try his metal is the school where he receives his technical training. His training to think logically and to speak and write clearly should go hand in hand with his technical training, not precede or follow it.

No doubt many schools are doing this very thing, but the writer mentions the matter here largely for the purpose of discussion and not to find fault with any particular curriculum.

REMARKS ON MINING EDUCATION.

D. J. Demorest.

Ohio State University.

I am interested in the work of your committee on Mining Education and have thought over your questionnaire quite a bit. We have been having almost countless committee meetings on this subject in the Engineering College here and have had so many divergent points of view that we have not been able to advance very far. There is always the struggle between the men who want to "educate students broadly first, and specifically in Mining and Metallurgy or some other engineering branch, second," and the men who want first to make thoroughly trained technicians out of the boys. Now as I see it the first and prime requisite is "a broad education," that is, that our boys should come to recognize themselves as related closely to the rest of mankind and then get built up in their minds the ideal of service and specifically service as engineers. To deliver this service will require, of course, a thorough technical training.

How then will we build a course in Mining and Metallurgy that will accomplish this end? The first requisite is one where we frequently fall down—we must have a strong faculty *animated with this ideal.* I declare that no course however cleverly built will accomplish the ends mentioned above without this carefully built faculty of teachers, and I believe the chief task of a director is to find the men and erect a faculty of the right caliber.

Having the right faculty then what shall be the curriculum? I am firmly impressed with the necessity of sticking to the four-year course for most students but a five-year curriculum should be offered to those students who have displayed first class ability. It would be a waste of his time to keep the general run of students in college five years but the excellent student can take good advantage of the fifth year. Granting that the four-year curriculum will be the usual one, what courses should be given in the four years? The prime idea in the scientific courses should be "a thorough training in the engineering fundamentals of chemistry, physics, mathematics to and through mechanics" without hastening to get thru these subjects to get to the more technical subjects. All the rest of the engineering course will be unsatisfactory unless these fundamentals are well done. And right here is one of our sins in engineering training—we allow the boys to be trained in these fundamentals by immature men who are unaware of the application of these subjects to engineering problems and worse yet these teachers are usually unaware that the important problem

before him is how to understand the men in his classes and interest them and get his teaching over to them. Really our chief problem in engineering training is not the student but the teacher. Assuming now that we have a pretty good faculty we will give two years of four or five hours each throughout the entire two years to chemistry, physics, and mathematics, with a course in engineering drawing also throughout the two years. I think it is also quite essential that for at least one hour per week the men should be addressed by mature men in the engineering profession on engineering ethics, citizenship, etc. Of course the usual physical education with its training in hygiene should be given throughout these two years. This fills the first two years.

Following in the third year we should have a year of mechanics of five hours throughout the year, a year of English (taught by a department under the control of the engineering college) of three hours, a year of elective of three hours under the control of the department giving the degree and the rest of the time given to technical studies. The fourth year should have three hours throughout the year of elective under the control of the department. The purpose of this elective is to give to each student that study which he most needs, maybe history or biology, English or economics, etc. The rest of the year should be given to technical studies, but at least five hours throughout the year should be given to "technical investigations" in which the men each or in groups investigate through carefully and thoroughly one or more subjects.

The course would in my opinion be stronger if at the end of the third year each student were required to spend an entire year in a mine or plant and make a complete report of the year before his fellow students and his teachers when he comes back. This would make a five-year course one of which would be spent remuneratively.

I think that the thing of importance in the above is that the engineering students must be thoroughly trained in their fundamentals before they are allowed to go farther, and that their teachers must study primarily the student and how to get the message over to him.

NOTES ON THE SUBJECT OF MINING AND METALLURGICAL EDUCATION IN REFERENCE TO THE RECENT GRADUATES OF MINING COLLEGES.

G. Chester Brown,

Chief Mining Engineer, California Industrial Accident Commission.

To me it appears that the following subjects have not been covered in the mining courses given by the colleges in this country.

1. A thorough course in composition so that the student will be able to intelligently express his thoughts and to convey to the reader the ideas that he has in mind.

2. A course in oral expression so that he may be able to verbally convey to his listeners the ideas he desires to express.

3. A practical course in the use and application of electrical equipment for mines.

4. A practical course in cost keeping and accounting.

5. A study of the care and use of hoisting ropes which might be embodied in the course now given in mining universities which is designated as "Strength of Materials."

6. The student should be impressed with the fact that the handling of men is of prime importance in his work. A course might be devised under the title of "The Human Element in Engineering." All of us realize that the human element is a very important factor in the success of any organization; this is especially true of the mining industry because the superintendent or the manager must, through his assistants convey to the employees the fact that he is human and that their welfare is his concern. Many mining companies have been wrecked because of the attitude of the manager, the superintendent and the bosses. For any venture to be a success, co-operation of the employees must be secured. I believe this important feature has been entirely overlooked in most of the mining colleges.

7. Another important point occurs to me which deals with mine safety work. The average student, upon graduating from a college of mines, has but a remote conception of the meaning of the phrase "Mine Safety." We all know that thousands of dollars per year are being spent in the various states in the Union in an endeavor to prevent injuries to the employes in the mines, yet the average student starts his life's work with a meager knowledge of this very important feature of the industry. Fatalities in the mines are very costly, not only because of the award to the dependents, but because the working place where this fatality occurs is abandoned for a time, and moreover, after a fatality, a number of the employees, especially the foreigners, leave the job.

A LIST OF REFERENCES ON ENGINEERING EDUCATION.

Compiled by Mrs. H. O. Norville, Librarian.

The following list of publications on Engineering Education is arranged chronologically with special courses, such as Metallurgical Engineering, Chemical Engineering, Mining and others included with the more general articles.

The list is of necessity short, and no attempt has been made to gather together material other than that available at the Missouri School of Mines. A key to the abbreviations will be found at the end of the list.

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Engineering education in relation to training for engineering work.—**E. McCullough.** A. S. C. E. Trans. Vol. 75, pp. 107-9-91, 1912. Discussion, pp. 1092-1147.

Training of engineers at Yale.—**T. Wilson.** Power, vol. 37, pp. 772-4, June 3, 1913.

Co-operative technical schools meet present needs.—**F. E. Ayer.** E. N., vol. 74, pp. 1059-1060, 1915.

Co-operative technical schools meet present needs. E. N., vol. 74, p. 1059-61, Dec. 2, 1915.

Engineering education faults.—**W. M. Wilson,** E. N., vol. 74, pp. 1211-13, Dec. 23, 1915.

Report of progress in the study of engineering education.—**C. R. Mann.** Soc. Prom. Eng. Educ. Bul., vol. 6, pp. 100-9, Oct., 1915.

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Education of engineers.—**C. R. Mann.** Col. Univ. Q., vol. 19, p. 56-73, Dec., 1916.

Subject treated under three headings: 1. Historical background. 2. Professional demand. 3. Work of the schools.

Engineering education in the United States.—**C. E. Howe.** C. E. S., Journ., vol. 8, pp. 417-38, May, 1916.

Development and requirements.

Engineering schools and industrial methods.—**H. L. Gantt.** E. M., vol. 51, p. 161, May, 1916.

English of engineers.—**J. M. Telleen.** C. E. S., Journ., vol. 19, pp. 97-112, Sept., 1916.

Criticism and suggestions, with general discussion.

An experiment in co-ordination of mathematics with engineering subjects.—**R. E. Root.** Eng. Ed., vol. 7, pp. 190-196, Dec., 1916.

How co-operative courses train young engineers.—**H. A. Stringfellow.** E. N., vol. 75, pp. 63-4, 1916.

Experiences of part school and part practice methods installed in the University of Rochester.

Influence of technical journalism on mining education (Read before the Pan.-Amer. Scientific Congress).—**T. A. Rickard.** M. & S. P., vol. 112, pp. 229-31, Feb. 12, 1916.

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Presidential address.

Pirate pills for engineers.—**L. M. Cox.** E. M., vol. 51, pp. 548-52, July, 1916.

Semi-humorous paper.

A proposed reorganization of engineering instruction for the Freshman and Sophomore years.—**L. E. Akeley.** Eng. Ed., vol. 7, pp. 197-210, Dec., 1916.

Report of progress in the study of engineering education.—**C. R. Mann.** Eng. Ed., vol. 24, pp. 48-66, Nov., 1916. Discussion, pp. 67-97.

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Some conditions affecting education in mining and metallurgy.—**J. C. Gwillim.** Can. Inst. Min., Bull., 46., pp. 161-67, Feb., 1916.

Suggestions for electrical research in engineering colleges.—**V. Karapetoff.** A. I. E. E., Trans., vol. 35, pt. 2, pp. 895-910, May, 1916. Discussion, pp. 911-23.

Topics suitable for thesis, research and advanced study.

Talk to young engineers.—**E. W. Rice.** Gen. El. R., vol. 19, pp. 1104-6, Dec., 1916.

Abstract of address at Schenectady. Problems to be faced by engineers.

"What is a college for?" Letters from **H. P. Boardman.** Eng. and Con., vol. 46, pp. 378-80, Nov. 1, 1916.

Reply to an editorial printed Sept. 20, 1916.

What manufacturers look for in engineering graduates.—**E. H. Fish.** E. M., vol. 51, pp. 673-677, Aug., 1916.

More attention should be paid to the "engineering of men" and less to the "engineering of materials."

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Education of the chemist.—**J. J. Dobbie.** Elect'n, vol. 79, p. 307.

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Engineering graduates and industrial demands.—**L. W. W. Morrow.** Eng. Ed., vol. 8, pp. 65-74, Oct., 1917. Same. E. N., vol. 79, pp. 1109-12, Dec. 13, 1917.

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School of chemical engineering practice—a year's experience.—**W. H. Walker.** Jl. Ind. & Eng. Chem., vol. 9, pp. 1087-89, Dec., 1917.

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Effect of war on engineering education.—**C. R. Mann.** Soc. Prom. Eng. Educ. Bul., vol. 9, pp. 108-18, Dec., 1918. Same. Eng. Ed., vol. 8, pp. 231-35, Feb., 1918. Same. Met. & Chem., vol. 18, pp. 133-34. Same. Power, vol., 47, pp. 217-218, Feb. 12, 1918.
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Perspective in engineering education.—**C. C. Williams.** Eng. Ed., vol. 8, pp. 226-9, 1918.

Present-day conditions are forcing the engineer to assume new responsibilities.—**C. R. Mann.** Eng. N., vol. 80, pp. 208-9, Jan. 31, 1918. Same. Met. & Chem., vol. 18, pp. 133-4, Feb. 1, 1918.

Safety and welfare work in the engineers' education.—**H. Follows.**—A. S. M. E., Journ., vol. 40, pt. 1, pp. 545-8, July, 1918.

Shall the case method be generally used in teaching engineering.—**S. Pritchett.** Eng. & Con., vol. 50, pp. 557-8, Dec. 11, 1918.

Teaching human engineering in the college curriculum.—**F. H. Rindge.** Am. Mach., vol. 48, pp. 713-15, April 25, 1918.

Three-year study of engineering education.—**C. R. Mann.** E. N., vol. 81, pp. 742-51, Oct. 24, 1918. Power, vol. 48, pp. 646-7. Oct. 29, 1918. Am. S. M. E. Journ., vol. 40, pp. 1060-1, Dec., 1918.

Proposes, not a standard curriculum, but a method by which engineering colleges can construct courses to meet present-day engineering demands which are fully outlined in the report.

Two-year engineering course urged by British engineer.—**E. J. Silcock.** E. N., vol. 81, pp. 353-4, Aug. 22, 1918.

Two-year engineering course urged by British engineer, to be followed by three years under Member of the Institution of Civil Engineers, would lead to associate membership. Is an abstract of discussions of the theory advanced by E. J. Silcock before the Institute of Water Engineers in England.

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Business training for the engineer.—**A. Marston.** E. & M. J., vol. 108, pp. 189-90, Aug. 2, 1919.

Carnegie Institute recasts course in mining engineering. Coal Age, vol. 16, pp. 112-13, July 17, 1919.

"Case system" changes in engineering curricula and business training for engineers. E. N., vol. 83, pp. 183-7, July 24, 1919.

Results at Army Engineer school at Camp A. A. Humphreys in applying definite problem method. Radical reorganization in methods of instruction effected at Tufts College and Yale University.

Co-operative course in electrical engineering. Elec. Wld., vol. 73, p. 1405, June 28, 1919.

Democratizing French engineering.—**F. Miltoun.** Iron T. R. vol. 64, pp. 704-5, March 13, 1919.

Education and training of municipal and county engineers; discussion. Eng. & Con., vol. 51, pp. 447-8, April 30, 1919.

Education in engineering. 1919 Iowa State College of Agriculture, Ames, Iowa.

Education of a petroleum engineer.—**J. H. Felgar.** Mech. Eng., vol. 41, pp. 816-17, Oct., 1919.

Enginering, Latin and Greek. E. & M. J., vol. 107, pp. 887-8, May 17, 1919.

Engineering educators take significant action at 27th annual meeting of S. P. E. E. E. N., vol. 83, p. 43. July 3, 1919.

Engineering colleges and administration.—**I. N. Hollis.** Eng. Ed., vol. 10, pp. 33-68, Oct., 1919.

Recommends that time of teacher be occupied with administration as little as possible, and that national engineering societies co-operate with Society for the Promotion of Engineering Education and with colleges themselves towards broadening out engineering education.

Engineering education.—**R. P. Baker.** 1919. Wiley.

Engineering education.—**F. Swain.** E. & M. J., vol. 107, p. 566, March 29, 1919.

Abstract.

Engineering education.—**F. L. Bishop.** U. S. Bureau of Education, 1919.

Engineering educators' opinions reflect past and predict future conditions. E. N., vol. 82, pp. 41-2; 138-43, Jan. 2, 16, 1919.

Engineering school of Liege.—**C. Clifton.** Engr., vol. 127, p. 497, May 23, 1919.

Essentials of engineering education.—**J. Flodin.** Ind. M., vol. 58, p. 312, Oct., 1919.

How educational reconstruction should develop.—**L. W. W. Morrow.** E. N., vol. 82, pp. 827-9, April 24, 1919.

Latin and Greek as preparation for engineering.—**M. E. Cooley.** E. N., vol. 82, p. 930, May 8, 1919.

Less theory and more horse sense in structural engineering courses. —**E. Godfrey.** Eng. & Con., vol. 51, p. 575-7, May 28, 1919.

Liberal element in engineering education.—**F. Swain.** Eng. & Con., vol. 52, pp. 733-4, Dec. 24, 1919.

More English, not Greek and Latin.—**W. G. Raymond.** E. N., vol. 82, pp. 1176-7, June 12, 1919.

Nonessentials of engineering education.—**E. H. Fish.** Ind. M., vol. 58, p. 46, July, 1919.

Objects of structural engineering courses.—**H. P. Gillette.** Eng. & Con., vol. 51, pp. 431-2, April 23, 1919.

Opinions of practicing engineers on teaching economics to engineering students. Eng. & Con., vol. 51, pp. 687-8, June 25, 1919.

Practicing engineers suggest lines of progress in engineering education; symposium. E. N., vol. 82, pp. 473-7, March 6, 1919.

Reflections on engineering and education.—**F. Hayford.** Eng. & Con., vol. 52, pp. 545-7, Nov. 5, 1919.

Short courses for engineering graduates.—**J. O. Kammerman.** Power, vol. 49, pp. 731-2, May 13, 1919.

Some remarks on co-operative methods of engineering education.—**V. Karapetoff.** Eng. Ed., vol. 10, pp. 101-104, Nov., 1919.

Emphasizes that "there is no universal method of education applicable to large groups of men, and that the problem is to keep on analyzing each student during his course, giving him such stimuli as he may need." Writer believes that summer vacation would be proper and natural time for practical experience, or whole year taken off before senior year.

Teaching pyrometry in teachnical schools.—**C. E. Mendenhall.** A. I. M. E., Bul., vol. 153, pp. 2143-5, Sept., 1919.

Technical training.—**M. L. Requa.** E. & M. J., vol. 108, pp. 63-4, July 12, 1919.

Tendencies in engineering education.—**P. E. Walker.** Ind M., vol. 58, pp. 445-7, Dec., 1919.

Influences coming as indirect results of war which may cause changes in engineering education are judged to be (1) changed economic conditions affecting both production and marketing of goods, and (2) impending changes in governmental attitude toward and demands on educational institutions.

Training in Latin and Greek not best for engineers.—**R. Hering.** E. N., vol. 82, pp. 1272-4, June 26, 1919.

Refuting M. E. Cooley in Engineering News Record, May 8, 1919, p. 930.

University training for engineers.—**W. Eliot.** Elec. Wld., vol. 73, pp. 683-4, April 5, 1919.

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Canadian demands in engineering education.—**C. H. Mitchell.** E. N., vol. 84, pp. 369-71, Feb. 19, 1920.

Co-operation between education and industry from the viewpoint of the manufacturer.—**R. D. Chapin.** Good Roads, N. S., vol. 20, pp. 119-20, 122-3, Sept., 1920. Same cond. Automotive Ind., vol. 43, pp. 278-9, Aug. 5, 1920.

Co-operation between engineering schools and the utilities. **H. B. Shaw.** Ind. M., vol. 60, p. 377-80, Nov., 1920.

Co-operation between the preparatory schools, the engineering colleges and industries as viewed from the standpoint of the educator. **A. M. Greene, Jr.** Eng. Ed., vol. 11, pp. 5-17, Sept., 1920.

Co-operation between schools and colleges says the author, is to be obtained by more extensive and thorough work in preparatory subjects of mathematics, English and sciences taught in school, and acceptance of this work by colleges between college and industry, he believes, co-operation will consist in more thorough and intense training, and special training required for industrial problems.

A co-operative course in electrical engineering conducted by M. I. T. and General Electric Co.—**W. H. Timbie.** Eng. Ed., vol. 10, pp. 459-76, June, 1920.

Covers period of five years, the first two years being identical with the regular course in electrical engineering at the Institute, and the last three years being divided between instruction in theory at the Institute and training in manufacturing methods at General Electric Company.

Distinctive features of a co-operative course in engineering.—**W. H. Timbie.** E. N., vol. 85, p. 119, July 15, 1920.

Abstract of a paper delivered before the annual meeting of the Society for the Promotion of Engineering Education.

Education of an engineer.—**R. W. Sorenson.** J. Elec., vol. 45, pp. 112-13, Aug. 1, 1920.

Education of the engineer.—**R. S. Woodward.** Chem. & Met., vol. 23, 926-8, Nov. 10, 1920.

Education of the research chemist.—**R. E. Rose.** Journ. Ind. & Eng. Chem., vol. 12, pp. 947-51, Oct., 1920.

Effect of railway conditions on civil engineering curricula.—**C. C. Williams.** Eng. & Con., vol. 54, pp. 164-6, Aug. 18, 1920.

Engineer in the making; symposium. J. Elec., vol. 45, pp. 110-12, Aug. 1, 1920.

Engineering college vs. arts college.—**P. B. McDonald.** Eng. & Con., vol. 53, pp. 710-11, June 23, 1920.

Engineering education. M. & S. P., vol. 121, pp. 223-4, 1920.

Engineering education.—**P. B. McDonald.** M. & S. P., vol. 121, p. 329, Sept. 4, 1920.

Engineering education and life.—**C. T. Brady.** E. N., vol. 84, pp. 31-2, Jan. 1, 1920.

Technical training, if broadened, should fit men for thousands of executive positions outside of engineering field.

The engineering educator's opportunity in engineering organizing. Eng. Ed., vol. 11, pp. 72-5, Oct., 1920.

Scheme of organization of engineering profession by means of Federated American Engineers' Societies is explained. Plan of federation completes formation of all—inclusive local societies of engineers in important communities and their organization into federation for action on matters dealing with public service.

Enrollment in engineering school greater than in 1917. E. N., vol. 84, pp. 10-11, Jan. 1, 1920.

Linking the technical school with the shop.—**H. R. Simonds.** Iron T. R., vol. 67, pp. 646-51, Sept. 2, 1920.

Plan adopted by M. I. T. in co-operation with the General Electric Company.

Metallurgical courses for automobile field.—**H. V. Dirks.** Iron Age, vol. 105, pp. 1245-6, April 29, 1920.

Shop courses in foundry, forging, heat treating and similar work established by Michigan Agricultural College.

Metallurgical research department of the Utah State School of Mines.—**L. W. Chapman.** Chem. & Met., vol. 22, pp. 877-81, May 12, 1920.

Professional spirit in engineering education.—**C. R. Mann.** Eng. N. R., vol. 84, pp. 1242-44, June 24, 1920.

Current schooling, it is said, is conspicuously designed to inspire the individual to make most of himself for the sake of his own success, while required training must inspire individual to make most of himself for the common good.

Relation of educational institutions to the industries.—**H. P. Talbot.** J. Ind. & Eng. Chem., vol. 12, pp. 943-7, Oct., 1920.

Robert college engineering school.—**L. A. Scipio.** Eng. Ed., vol. 11, pp. 32-6, Sept., 1920.

Scientific research in the engineering schools.—**A. E. Kennelly.** Elec. Wld., vol. 75, pp. 150-1, Jan. 17, 1920.

Shop course in metallurgy at the Michigan Agricultural college.—**H. B. Dirks.** Am. Mach., vol. 52, pp. 961-2, April 29, 1920.

Some forces in engineering education.—**H. A. Watt.** E. N., vol. 84, pp. 771-3, April 15, 1920.

Technical education through university extension.—**R. J. Heffner.** J. Elec., vol. 44, pp. 56-7, Jan. 15, 1920.

What a production engineer should know.—**A. McDonald.** Ind. Man., vol. 60, pp. 185-7, Sept., 1920.

Outlines requirements for course in production engineering.

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Address to mining students.—**F. Laist.** M. & S. P., vol. 123, pp. 21-6, July 2, 1921.

Commencement address of the Colorado School of Mines at Golden on June 10, 1921.

The college-trained engineer.—**C. E. Magnusson.** A. I. E. E., Journ., vol. 40, pp. 730-36, Sept. 1, 1921.

Columbia School of Mines idea.—**G. J. Young.** E. & M. J., vol. 111, pp. 744-46, April 30, 1921.

Six years' course established by Columbia University. First three years form basis of liberal education and last three years are devoted to technical studies.

Educating of the mining engineer.—**W. S. Weeks.** M. & S. P., vol. 122, pp. 321-3, March 5, 1921.

Education of mining engineers.—**E. A. Allcut.** Eng. & Ind. M., vol. 6, pp. 633-37, Dec. 1, 1921.

Refers to lack of co-ordination in connection with early training of engineers and points out discrepancies (starting at elementary schools) with view to their ultimate disappearance or modification.

Engineering college registration shows four per cent gain. E. N. Rec., vol. 86, pp. 1104-6, June 30, 1921.

Census by Engineering News Record covered 43,312 students in 81 institutions located in 36 states. Mechanical engineering was the most popular course.

Engineering courses should be of professional grade.—**H. Burr.** Eng. & Con., vol. 56, pp. 180-1, Aug. 24, 1921. Same E. N., vol. 87, pp. 65-6, July 14, 1921.

Argues that technical study should be preceded by three years of general college work.

Engineering education at Harvard. E. N., vol. 86, pp. 594-5, April 7, 1921.

Engineering in Japan.—**F. Mason.** E. & M. J., vol. 111, p. 12, Jan. 1, 1921.

Engineering societies and engineering education.—**N. Hollis.** Eng. Ed., vol. 11, pp. 94-135.

Essentials of an engineering education.—**A. J. Wood.** Mech. Eng., vol. 43, pp. 420-1, June, 1921.

General education and the engineering profession.—**H. E. Miles.** Mech. Eng., vol. 43, pp. 517-20; 550, 1921.

Points out lack of vocational schools in schools in the United States and need for longer school year. Notes on continuation schools and training of teachers.

How should the engineer be educated? Am. Mach., vol. 54, pp. 1105-9, June 30, 1921.

Views of prominent educators and of employers of engineers.

Making better engineers of college men; power to think is more important than mind filled with facts. Elec. W., vol. 78, pp. 567-9, Sept., 1921.

Michigan College of Mines in the nineteenth century.—**M. E. Wadsworth.** Eng. Ed., vol. 11, pp. 2306-5, Jan., 1921.

New engineering ideals.—**I. O. Baker.** A. S. C. E., Proc., May, 1921. Same. Eng. & Con., vol. 56, pp. 235-6, Sept. 7, 1921.

Recent developments at the University of Cincinnati. E. N., vol. 87, pp. 277-9, Aug. 18, 1921.

Requirements of the engineering industries and the education of engineers; the Schneider plan as applied to the co-operative plan between the General Electric Company and M. I. T.—**M. W. Alexander.** Mech. Eng., vol. 43, pp. 391-5, June, 1921.

Developments in organization of co-operative engineering courses in connection with manufacturing plants. Plan organized at M. I. T. and Lynn works of The General Electric Company. During their assignments at works, students are subject to usual rules and regulations applying to employees of General Electric Co.

The scarcity of the college-trained engineer in production.—**J. Airey.** Eng. Ed., vol. 11, pp. 290-97, Feb., 1921.

Suggests college engineering institution spend transitory period as foremen in factory instead of in office or laboratory. This, it is believed, would fit them better to direct production in industry properly.

Scholarship and eminence in engineering.—**R. Walters.** Eng. Ed., vol. 11, pp. 361-77, April, 1921.

Study of scholastic training of group of eminent engineers conducted under auspices of the American Association of Collegiate Registrars showed "close correspondence between good scholarship in collegiate courses and professional eminence in engineering."

Technical education; Discussion of report of Committee on Technical Education, by the New York section of the Mining and Metallurgical Society of America, October 28, 1921. Min. & Met. Soc. of Amer., Bul., vol. 14, pp. 212-36, Dec. 31, 1921.

Training for foreign exploration.—**H. F. Bain.** M. & S. P., vol. 123, pp. 55-60, July 9, 1921.

Commencement address, Missouri School of Mines, April 29, 1921.

Training the engineer for industrial and social service. E. N. Rec., vol. 87, pp. 979-81, Dec. 15, 1921.

Two engineering educators discuss professional and nonprofessional opportunities of the young engineer and length of course justified in preparing him for service. (1) Projecting professional ideas into business.—**Frederic Bass.** (2) Visioning the opportunity of the engineer.—**Hale Sutherland.**

What our engineering colleges owe our industries.—**R. Matthews.** Ind. M., vol. 61, pp. 155-8, March 1, 1921.

More character building even at expense of specialized training urged to supply industry with leaders who have human touch.

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College of Engineering of the Newark Technical school. Chem. Age, vol. 30, pp. 11-4, Jan., 1922.

The universities and the engineering profession.—**F. D. Adams** Can. Inst. Min., Bul., vol. 117, pp. 73-6, Jan., 1922.

Changes in engineering courses of instruction.—**F. B. Sanborn.** Eng. Ed., vol. 12, pp. 170-174, Dec., 1921.

Development of special courses in English for engineering students.—**J. R. Nelson.** Eng. Ed., vol. 12, pp. 104-113, Nov., 1921.

Engineering education; the development of the resourceful mind.—**J. G. Hibben.** Mech. Eng., vol. 44, pp. 204-205, Mar., 1922.

Engineering education as viewed by the industrialist.—**J. E. Otterson.** Mech. Eng., vol. 44, pp. 5-6; same, E. N., vol. 88, pp. 275-277, Feb. 16, 1922.

Later work, not education, raises professional status.—**C. A. Holden.** E. N., vol. 87, p. 949, Dec. 8, 1921.

National policy on engineering education.—**A. G. Christies.** Mech. Eng., vol. 44, pp. 3-5, Jan., 1922.

Training the engineer for industrial and social service. E. N. Rec., vol. 87, pp. 979-981, Dec. 15, 1921.

Visioning the opportunity of the engineer.—**H. Sutherland.** E. N., vol. 87, pp. 980-981, Dec. 15, 1921.

ABBREVIATIONS USED.

A. El. S.—American Electrochemical Society. Bulletin.

A. I. E. E.—American Institute of Electrical Engineers.
Transactions.
Journal.

A. S. C. E.—American Society of Civil Engineers. Trans.

A. S. M. E.—American Society of Mechanical Engineers.

Am. Mach.—American Machinist.

Automotive Ind.—Automotive Industries.

Soc. Prom. Eng. Educ. Bul.—Society for the Promotion of Engineering Education. Bulletin. *See also Engineering Education.*

Can. Min. Inst.—Canadian Mining Institute. Bulletin.

Chem. & Met.—Chemical and Metallurgical Engineering. Formerly Metallurgical and Chemical Engineering.

Chem. Age.—Chemical Age.

C. E. S.—Cleveland Engineering Society. Journal.

C. U. Q.—Columbia University Quarterly.

E. & M. J.—Engineering and Mining Journal.

E. Cb. St. L.—Engineers' Club of St. Louis. Journ.

E. M.—Engineering Magazine. Now Industrial Management.

E. N.—Engineering News.

E. N. Rec.—Engineering News-Record.

El. R.—Electrical Review.

Elec. Wld.—Electrical World.

Elect'n.—Electrician. (London.)

Engr.—Engineer. (London.)

Eng. & Con.—Engineering and Contracting.

Eng. Ed.—Engineering Education. Bulletin of the Society for the Promotion of Engineering Education.

Gen. El. R.—General Electric Review.

Good Roads.—Good Roads.

Ind. M.—Industrial Management. Formerly Engineering Magazine.

Iron Age.—Iron Age.

Iron T. R.—Iron Trade Review.

J. Elec.—Journal of Electricity.

Jl. Ind. & Eng. Chem.—Journal of Industrial and Engineering Chemistry.

M. & S. P.—Mining and Scientific Press.

Mech. Eng.—Mechanical Engineering, Journal of the American Society of Mechanical Engineering.

Met. & Chem.—Metallurgical and Chemical Engineering. Now Chemical and Metallurgical Engineering.

Min. & Met. Soc. Amer., Bul.—Mining and Metallurgical Society of America. Bulletin.

Power.—Power.

Sibley J.—Sibley Journal.

Soc. Prom. Eng. Ed.—Society for the Promotion of Engineering Education.

West. Soc. Engrs.—Western Society of Engineers. Journal.

BULLETINS OF THE MISSOURI SCHOOL OF MINES.

GENERAL SERIES.

Vol. 1, No. 1, Dec., 1908. The human side of a mining engineer's life. Edmund B. Kirby. (Commencement address, June 10, 1908.)

Vol. 1, No. 2, 38th Annual Catalogue, 1909-1910.

Vol. 1, No. 3, June, 1909. Education for utility and culture. Calvin M. Woodward. (Tau Beta Pi Address.)

Vol. 1, No. 4, Sept., 1909. The history and development of the cyanide process. Horace Tharp Mann.

Vol. 2, No. 1, Dec., 1909. The Jackling field, School of Mines and Metallurgy.

Vol. 2, No. 2, 39th Annual Catalogue, 1910-1911. (*Out of print.*)

Vol. 2, No. 3, June, 1910. Some of the essentials of success. Charles Summer Howe. (Commencement address, June 1, 1910.)

Vol. 2, No. 4, Sept., 1910. Friction in small air pipes. E. G. Harris, Albert Park, H. K. Peterson. (Continued by Technical Series. Vol. 1, Nos. 1 and 4.)

Vol. 3, No. 1, Dec., 1910. Some relations between the composition of a mineral and its physical properties. G. H. Cox, E. P. Murray.

Vol. 3, No. 2, March 1, 1911. 40th Annual Catalogue, 1911-1912.

Vol. 3, No. 3, June, 1911. Providing for future generations. E. R. Buckley. (Tau Beta Pi address, May 24, 1911.)

Vol. 3, No. 4, Sept., 1911. Fall announcement of courses. (*Out of print.*)

Vol. 4, No. 1, Dec., 1911. Fortieth anniversary of the School of Mines and Metallurgy of the University of Missouri. Parker Hall Memorial Address. Laying of cornerstone of Parker Hall, Rolla, Missouri, October 24, 1911. (*Out of print.*)

Vol. 4, No. 2, March, 1912. 41st Annual Catalogue, 1912-1913. (*Out of print.*)

Vol. 4, No. 3, June, 1912. Mining and civilization. J. R. Finlay. (Commencement address, May 31, 1912.)

Vol. 4, No. 4, Sept., 1912. Fall announcement of courses. (*Out of print.*)

Vol. 5, No. 1, Dec., 1912. Student life.

Vol. 5, No. 2, March, 1913. 42nd Annual Catalogue, 1912-1913.

Vol. 5, No. 3. Never published.

Vol. 5, No. 4. Never published.

Vol. 6, No. 1. Never published.

Vol. 6, No. 2, March, 1914. 43rd Annual Catalogue, 1913-1914.

Vol. 6, No. 3. Never published.

Vol. 6, No. 4. Never published.

Vol. 7, No. 1. Never published.

Vol. 7, No. 2, March, 1915. 44th Annual Catalogue, 1914-1915.

Vol. 7, No. 3, June, 1915. Description of special courses in oil and gas and allied subjects.

Vol. 7, No. 4, Sept., 1915. Register of graduates, 1874-1915.

Vol. 8, No. 1, Jan., 1916. Bibliography on concentrating ores by flotation. Jesse Cunningham.

Vol. 8, No. 2, March, 1916. 45th Annual Catalogue, 1915-1916. (*Out of print.*)

Vol. 8, No. 3, June, 1916. The business of mining. W. R. Ingalls. (Commencement address, May 26, 1916.)

Vol. 8, No. 4, Oct., 1916. Register of graduates, 1874-1916. (*Out of print.*)

Vol. 9, No. 1, Jan., 1917. Road problems in the Ozarks. E. G. Harris. Bibliography on rural roads. H. L. Wheeler.

Vol. 9, No. 2, March, 1917. 46th Annual Catalogue, 1916-1917.

Vol. 9, No. 3, June, 1917. What should a present-day metallurgical education comprise? Charles Hermann Fulton. (Commencement address, May 25, 1917.)

Vol. 9, No. 4, Oct., 1917. Register of graduates, 1874-1917. M. S. M. men in military service.

Vol. 10, No. 1, Jan., 1918. Student life; revised edition.

Vol. 10, No. 2, March, 1918. 47th Annual Catalogue, 1917-1918.

Vol. 10, No. 3, June, 1918. The human side of mining engineering. James Furman Kemp. (Commencement address, May 24, 1918.)

Vol. 10, No. 4, Oct., 1918. (Delayed.) List of publications wanted by the library, and of duplicates available for sale or exchange, April, 1920.

Vol. 11, No. 1, Jan., 1919. Never published.

Vol. 11, No. 2, March, 1919. 48th Annual Catalogue, 1918-1919.

Vol. 11, No. 3, June, 1919. Road problems in the Ozarks; 2nd edition, revised and extended. E. G. Harris. Bibliography on rural roads. H. L. Wheeler.

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Vol. 12, No. 1, Jan., 1920. War service records of the Missouri School of Mines. Compiled by G. E. Ebmeyer.

Vol. 12, No. 2, March, 1920. 49th Annual Catalogue, 1919-1920.

Vol. 12, No. 3, June, 1920. Contemporary novels and novelists; a list of references to biographical and critical material; for English 421. H. L. Wheeler.

Vol. 12, No. 4, October, 1920. Department of Vocational Education.

Vol. 13, No. 1, Jan., 1921. Register of graduates, 1874-1921.

Vol. 13, No. 2, March, 1921. 50th Annual Catalogue, 1920-1921.

Vol. 13, No. 3, June, 1921. Training for exploration. H. Foster Bain. (Commencement address, April 29, 1921.)

Vol. 13, No. 4, October, 1921. Department of Vocational Education.

Vol. 14, No. 1, January, 1922. Symposium of Mining and Metallurgical Education.

Vol. 14, No. 2, March, 1922. 51st Annual Catalogue, 1921-1922.

TECHNICAL SERIES.

Vol. 1, No. 1, Nov., 1911. Friction in air pipes. E. G. Harris. (Continuation of General Series, Vol. 2, No. 4.)

Vol. 1, No. 2, Feb., 1912. Metallurgy and ore dressing laboratories of the Missouri School of Mines and Metallurgy. D. Copeland, H. T. Mann, H. A. Roesler. (*Out of print.*)

Vol. 1, No. 3, May, 1912. Some apparatus and methods for demonstrating rock drilling and the loading of drill-holes in tunneling. L. E. Young.

Vol. 1, No. 4, Aug., 1912. Friction in air pipes. E. G. Harris. (Continuation of Vol. 1, No. 1, Nov., 1911.)

Vol. 2, No. 1, Aug., 1915. Comparative tests of piston drill-bits. C. R. Forbes and L. M. Cummings.

Vol. 2, No. 2, Nov., 1915. Orifice measurements of air in large quantities. Elmo G. Harris.

Vol. 2, No. 3, Feb., 1916. Cupellation losses in assaying. Horace T. Mann and Charles Y. Clayton.

Vol. 2, No. 4, May, 1916. Geologic criteria for determining the structural position of sedimentary beds. G. H. Cox and C. L. Dake. (*Out of print.*)

Vol. 3, No. 1, Aug., 1916. Experiments from the flotation laboratory. C. Y. Clayton. (*Out of print.*)

Vol. 3, No. 2, Nov., 1916. Studies on the origin of Missouri cherts and zinc ores. G. H. Cox, R. S. Dean and V. H. Gottschalk.

Vol. 3, No. 3, Feb., 1917. Preliminary report on blended Portland cement. E. S. McCandliss.

Vol. 3, No. 4, May, 1917. Studies in the production of oils and tars from bituminous materials. J. C. Ingram.

Vol. 4, No. 1, Aug., 1917. The hydrometallurgy and electrolytic precipitation of zinc. F. D. James.

Vol. 4, No. 2, Nov., 1917. The effect of addition agents in flotation. Part I. M. H. Thornberry and H. T. Mann.

Vol. 4, No. 3, Feb., 1918. Bibliography: Roasting, leaching, smelting, electric smelting and electrolysis of zinc. H. L. Wheeler.

Vol. 4, No. 4, May, 1918. An investigation of blended Portland cement. E. S. McCandliss and H. H. Armsby.

Vol. 5, No. 1, Aug., 1919. The carbonization of Missouri cannel coals. H. L. Dunlap, K. K. Kershner and V. X. Smiley.

Vol. 5, No. 2, Nov., 1919. The effect of addition agents in flotation. Part II. M. H. Thornberry and H. T. Mann.

Vol. 5, No. 3, Feb., 1921. An investigation of the xylenes obtained from the carbonization of coal. W. D. Turner. (*In press.*)

Vol. 5, No. 4, May, 1921. Coal mining methods in Missouri. W. W. Weigel.

Vol. 6, No. 1, August, 1921. The problem of the St. Peter Sandstone. C. L. Dake.

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